

Applying Grounded Theory to Understand Software Process Improvement Implementation

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Abstract— Recent studies show that many organizations struggle to implement Software Process Improvement (SPI) based on process models and standards mainly because of incapacity to overcome critical barriers, such as lack of motivation and higher management support. The accurate understanding of the social-cultural context where SPI is undertaken can facilitate the development of more efficient SPI implementation strategies aiming to overcome those difficulties. The objective of this work is to present a Grounded Theory based study conducted to investigate SPI implementation initiatives in the perspective of consultants of SPI consultancy organizations. The main product of this study is a theoretical framework that tries and explains the phenomenon associated to the success of SPI implementation initiatives.

Grounded Theory; Software Process Improvement (SPI)

I. INTRODUCTION

Software Process Improvement (SPI) implementation initiatives have been largely conducted in software organizations aiming to adhere to ‘best practices’ advocated by process reference models. Nevertheless, recent studies show that many organizations struggle to implement SPI mainly because of incapacity to overcome critical barriers, such as lack of motivation and higher management support [1][2]. The accurate understanding of the social-cultural context where SPI is undertaken can facilitate the development of more efficient SPI implementation strategies aiming to overcome those difficulties.

The objective of this work is to present a study conducted to investigate SPI implementation initiatives in the perspective of consultants of SPI consultancy organizations. The methodology chosen to guide the study is Grounded Theory because it is indicated to study human behavior and organizational cultures [3][4]. By using Grounded Theory, we could develop an accurate understanding of the meaning, experiences, events and the reality of the phenomenon associated to the success of SPI implementation initiatives.

This paper is organized as follows: Section 2 presents some qualitative studies that applied Grounded Theory. Section 3 presents the research methodology. The application of Grounded Theory is presented in Section 4. Section 5 presents the research results. A discussion about the contributions of the study results and its implications for SPI research and practice,

and the limitations of the study are presented in section 6. Finally, some concluding remarks and the next steps are presented in Section 7.

II. USING GROUNDED THEORY IN QUALITATIVE STUDIES

Despite the fact that Ground Theory was originated in the late 60’s and that it has been extensively applied in the social sciences areas; the use of Grounded Theory in software development studies is not very common and is usually restricted to investigate technological issues in Information Systems. In the Software Engineering and SPI implementation areas, the Grounded Theory studies are relatively rare. Nonetheless, there is some relevant work that should be highlighted.

One interesting study describing the application of Grounded Theory is presented by Orlikowski [6]. In this work, the author characterizes two organizations’ experiences with the adoption and use of CASE tools. Some of the findings of this work suggest that the implementation of CASE tools can be better managed if practitioners recognize that CASE tools implementation is not a merely technology installation, but it involves a process of organizational change over time. Although this work does not focus specifically in SPI, the findings have important implications for SPI research and practice, since CASE tool implementation can be interpreted as one variation of process improvement. Although this work emphasizes the adequacy of the Grounded Theory methodology to investigate the social context that permeates the introduction of process improvements, its results do not provide applicable knowledge aiming to overcome the barriers for successfully implementing SPI.

Another work in the SPI area describing interest results with the adoption of Grounded Theory is presented by Coleman and O’Connor [7]. The authors investigated software process practice in the Irish software industry and concluded that SPI programmes are implemented reactively and that there is some resistance by software managers to implement SPI best practices models because of the associated costs. In spite of the fact of the great implications for the SPI area, these results are context dependent, and, as a consequence have limited use in different scenarios.

Nasirin et al. present the application of grounded theory approach to investigate the critical success factors of Geographical Information Systems (GIS) implementation [5]. The authors recognize that grounded theory was useful to characterize not only the organizational context of GIS implementation activities, but also the effective practical solutions to successfully implement GIS. Although this study did not focused in SPI specifically, it demonstrates the benefits and feasibility of the application of grounded theory approach in qualitative studies conducted to understand the critical success factors and the implementation strategies to effectively introduce organizational changes.

Crabtree et al. applied the grounded theory approach to guide a study aiming to investigate behavioral aspects concerning software process descriptions in natural language [6]. The authors developed a theory that explains the dependency relationships between descriptions of process and cognitive perspectives shaped by the elicitation and process context. Despite the fact that the study results demonstrate the adequacy of grounded theory to conduct investigations in the SPI area, further investigations are still necessary to assess the generality of the developed theory.

III. RESEARCH METHODOLOGY

In order to support the application of Grounded Theory methodology, we developed a procedure based on the descriptions of the components of Grounded Theory presented in [3][7][10]. This procedure is described in the following.

A. Step 1 - Define the Context and Scope of the Study

First, the context and scope of the study of a specific phenomenon shall be defined. The fundamental aspect of Grounded Theory is that a theory is developed in an inductive way from data, being derived (or grounded) in a continuous process of data collection and analysis [3]. Multiple sources of data shall be used aiming both to increase the confiability of the results and to facilitate capturing knowledge, vision and perspective of the people involved in the study under a specific aspect of the phenomenon under investigation [7][10].

B. Step 2 - Define and Apply Mechanisms for Collecting Data

The recommended mechanisms to support data collection are the following: (i) experimental studies like surveys, (ii) literature review and (iii) structured and semi-structured interviews. These three types of mechanisms are considered as the most common and applicable in qualitative studies [7][10].

The application of these mechanisms facilitates the creation of a data repository (or slices of data using Grounded Theory jargon) that can be used during the investigation of a specific phenomenon. The use of supporting tools is also an important issue aiming to facilitate not only the storage of these data, but also its retrieval and analysis. In the context of this study, we used a tool named ATLAS.ti developed specifically to support the conduction of Grounded Theory based investigations.

C. Step 3 - Perform Open Coding of the Data

Once the data were collected, the analyses can be initiated. The dynamic relation between data collection and analysis is a significant characteristic of Grounded Theory [7]. The data analysis oriented by Grounded Theory is performed by data coding. There are three different types of codification: open, axial and selective coding. Open coding or labeling involves breaking, analyzing, comparing, conceptualizing and categorizing the collected data. In the axial coding process, the relations between categories and subcategories of the data are analyzed. The selective coding refines all the process by identifying the central category of the theory from which all the others are related.

The objective of this specific step is two fold: (i) to perform the open coding of the data and (ii) to group the codes in categories and subcategories. In this context, the coding involves the process of creating labels (or codes) to describe relevant concepts and aspects of certain texts passages in the data sources [11]. The data analysis is performed by (i) searching for aspects that reflect similarities or differences between the data, and (ii) collecting a relevant number of indicators that point to multiple qualitative aspects of potentially significant concepts.

D. Step 4 - Perform Axial Coding of the Data

The objective of this step is to aggregate knowledge about the theory. In Grounded Theory, the investigation process for construction of a theory is guided by a model named Paradigm Model [3]. According to this model, knowledge is aggregated to a theory by analyzing and constructing relations between categories and subcategories that shall be tested again in the data. Grounded Theory defines this type of analysis as axial coding. In order to facilitate the data collection and analysis in the context of this study, we developed a meta-model that defines the concepts of the Paradigm Model and its relationships. Fig. 1 depicts this meta-model. The theory was developed in this study as a result of the direct instantiation of the meta-model.

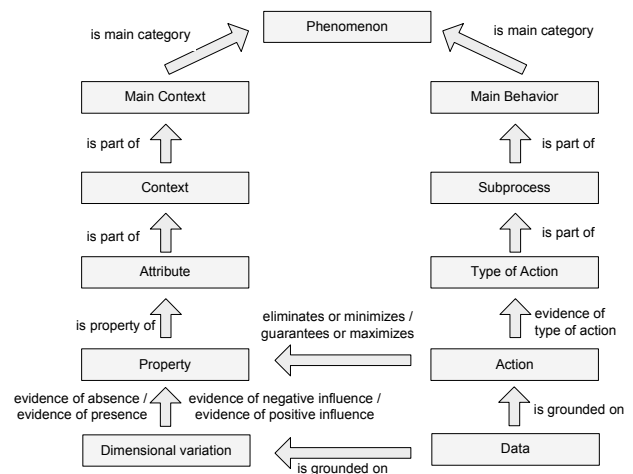


Figure 1. Meta-model for developing Grounded Theory.

The fundamental concept in every Grounded Theory study is the *Data*. The data can be represented as text passages documented, for instance, in the form of interview transcripts or literature reports. According to the meta-model depicted in Fig. 1, the data representing significant aspects of the phenomenon under study can be categorized in one of these two distinct types of codes: *Dimensional variation* and *Action*. The first one represents a code that categorizes a specific type of variation of a *Property*. The former one can be used to categorize actions of a specific *Type of Action*. Properties characterize *Attributes* (or concepts) that are part of specific *Context* relevant for understanding the phenomenon. Types of action characterize a *Subprocess* that models a specific behavioral aspect of actors within specific contexts. In the final stages of the Grounded Theory studies, more abstract codes are derived corresponding to the *Main Context* and *Main Behavior* of the developed theory that aggregates all the other codes.

In order to facilitate the hierarchical categorization of these concepts, we defined a set of connectors. These connectors are represented in the meta-model of Fig.1 as labels of the arrows. The relations between the categories and subcategories are defined in the form of propositions (or hypotheses), representing casual conditions, phenomenon, context, intervening conditions, action/interaction strategies and consequences. The construction of a theory shall be guided by the continuous search for connections between instances of these elements, represented in the form of propositions or hypotheses grounded on the collected data.

E. Step 5 - Perform Selective Coding of the Data

The objective of this step is to refine the knowledge about the constructed theory by what Grounded Theory denominates of selective coding. In this step, all the theory construction process is refined by identifying the central category from which all the other categories are related. The central category shall be capable to integrate all the other categories and to express the essence of the social process underlying the phenomenon under investigation [10]. The construction of a theory grounded on data shall be performed iteratively as more data is collected and analyzed. This iterative process of collecting, coding and analyzing data whilst simultaneously generating theory is also referred as theoretical sampling.

During the iterations of the research process, more knowledge about the theory is aggregated and refined until the collection and analysis of more data do not provide significant gains to the theory, i.e., new categories and relations are no longer identified in the codification process. When this occurs, theoretical saturation is achieved [3].

F. Step 6 - Audit the study

The Audits technique shall be applied during the investigation process aiming to guarantee validity of the results [10]. Therefore, it is important to register annotations during the research process, since the data collection step until the codification and analysis of the building blocks of the theory. The application of Audits technique shall be guided by a set of criteria and conducted by a person that were not involved in the research process aiming to guarantee objectivity of the assessment. Examples of criteria applicable to theory

assessments are: degree of coherence, relevance, flexibility and density [10].

IV. THE GROUNDED THEORY STUDY

In order to focus the application of the Grounded Theory methodology, the following research questions were investigated in two distinct phases of the study: (RQ1) *What are the factors that have influence on the success of software process improvement initiatives?* and (RQ2) *How SPI practitioners address the factors that have influence on the success of software process improvement initiatives?*. Fig. 2 depicts the structure of the Grounded Theory study. The application of the methodology in the two phases of the study is presented in the following.

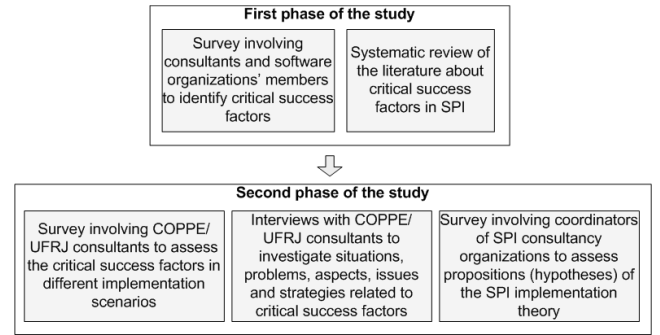


Figure 2. Structure of the Grounded Theory study

A. First Phase of the Study

The first phase of the study was restricted to analyze only the experiences of SPI consultants and members of organizations involved in SPI initiatives. The detailed application of the Grounded Theory methodology to guide the first phase of the study is presented in [14] and briefly described in the following.

The participants of the study were selected from a group of Brazilian consultancy organizations with successful experiences in SPI initiatives based on CMMI [12] and also on the Brazilian software process model named MR-MPS [13]. We also selected members of the organizations that were the focus of the SPI initiatives coordinated by those organizations.

We collected the data by applying two types of questionnaires, one to SPI consultants and the other to organization members, aiming to identify factors that have influence in SPI implementation. In total, 25 questionnaires were returned containing general descriptions about factors that had influenced SPI initiatives. We considered that the varied experiences of the survey participants were adequate to perform an initial investigation on SPI practitioners' perceptions about critical success factors.

The questionnaires were analyzed aiming to classify each text passage in a category representing a type of finding of a factor that had influenced, either in a positive or negative way, the success of software process initiatives. From the analyses of the 25 questionnaires, we were able to identify 66 different categories (codes) of critical success factors findings types.

Due to the exploratory nature of the first phase of the study, we considered relevant to conduct a study based on systematic review with the purpose of identifying the factors that have influence on SPI initiatives. From the execution of this review, we selected 10 relevant experimental studies. Then, we analyzed the descriptions of the factors, provided in the studies, aiming to associate them to one of the 66 codes of types of critical success factors identified from the analyses of the questionnaires of the survey. It was not possible to associate all the factors to one of those codes. Therefore, we created more 10 codes for the unclassified factors. In total, we identified 25 codes of properties related to 12 critical success factors.

The theoretical knowledge was aggregated by performing axial coding of the data that implies performing analyses and construction of relations between the identified codes. There was no previous knowledge about the critical success factors. Therefore, we tried to overcome the difficulties of identifying relations between the codes by applying statistical data analyzes to support the construction of statistical significant relations between the collected data. In this context, we applied the MDS and PCA statistical analyses techniques aiming to derive and aggregate principal components of critical success factors. We named “Component of Critical Success Factor” the set of properties of critical success factors with statistically significant relations. In total, 5 components were identified. Table I presents these components and the critical success factors properties with statistical relationship.

TABLE I. COMPONENTS OF CRITICAL SUCCESS FACTORS

#	Properties of Critical Success Factor
1	Organization members' competences in software engineering Lack of conflicts of interests in SPI Organizational internal stability Organization members' satisfaction Existence of acknowledgement politics to SPI collaboration Relationship among organization members and SPI consultants
2	Organization members' awareness of SPI benefits Adequacy of SPI project management
3	Adequacy of SPI push-pull implementation relation People turnover Adequacy of processes and procedures Complete SPI institutionalization
4	Higher management support, commitment and involvement Organization members' competences in software engineering Availability of financial resources to SPI Availability of organization members' time to SPI
5	Acceptance to changes Organization members' motivation to SPI Trustfulness of organization members in the SPI consultants

Factor 1 was labeled “Environment” since all variables measure the organizational environment capability to establish and maintain SPI initiatives. Factor 2 is labeled “Efficient SPI Implementation Strategy” and indicates that an efficient SPI strategy is concerned on guaranteeing that organization members are aware of the potential benefits that can be achieved by implementing SPI. We named Factor 3 component as “Solid SPI Implementation” since the variables of this factor measure the solidification of SPI implementation initiatives across the organization by characterizing the processes and procedures institutionalization resistance degree to

organizational structure changes. Since all variables of Factor 4 component are considered indicators of commitment to SPI, we labeled this factor as “Commitment”. Factor 5 is termed “SPI motivation and acceptance” and indicates that the SPI team is a facilitator of organization members' acceptance to institutionalization of process changes promoted by SPI initiatives.

B. Second Phase of the Study

The second phase of the study was restricted to analyze the experiences of a group of SPI consultants of a specific consultancy organization. The selected institution for this study was COPPE/UFRJ, due to the easy access to its consultants and the high number of successful SPI initiatives coordinated by that institution. The consultants of this institution coordinated more than 30 SPI implementation initiatives that had conducted successful official assessments based on process reference models, like CMMI.

Firstly, we collected data by executing a survey involving the consultants of COPPE/UFRJ aiming to identify the most critical success factors in specific SPI implementation contexts. We began by identifying all the information of the past SPI initiatives coordinated by COPPE/UFRJ. After that, each initiative was categorized in a specific scenario according to the actual maturity level of the organizational unit that was the focus of the implementation activities and the intended maturity level.

We defined a questionnaire to support the execution of the survey with the consultants of this organization. The questionnaire contained a matrix relating the critical success factors (measured by its properties extracted from the theory constructed in the first phase of the study) and the implementation scenarios that the participants of the study were significantly involved. The questionnaire was sent to each of the 16 consultants involved in the SPI initiatives coordinated by COPPE/UFRJ. All the consultants returned the questionnaires that were consolidated according to the role of each participant in the implementation scenarios. Some of the participants identified other factors, besides those presented in the questionnaire. The results of the answers of the participants of the study were consolidated in the different implementation scenarios. Each factor was analyzed trying to identify the scenarios that the factor was evaluated as high criticality or critical for each of the groups. The result of the survey was that all the critical success factors were evaluated as high criticality or critical by all the groups of participants of the study in one or more scenarios.

Next, we conducted a series of interviews with the consultants aiming to investigate about what are the situations, problems, aspects or issues that have either positive or negative influence on the presence of the critical success factors. In total, we interviewed 6 experienced SPI consultants divided into three groups according to their profile (1 coordinator of the consultancy organization, 2 SPI project managers and 3 SPI implementation team members). The interviews also aimed to investigate how a consultancy organization can help to guarantee and maximize the positive influence or eliminate and minimize the negative influence of the critical success factors.

By analyzing the interview data, we elaborated a set of 200 propositions associated to each of the critical success factors. These propositions were assessed by the interviewees that suggested modifications, when appropriate. After the assessment of the propositions by the SPI consultants, we performed an analysis on the data aiming to identify the core and main categories of the theory.

V. RESEARCH RESULTS

The Grounded Theory methodology supports the development of theories in a systematic way from collecting and analyzing data originated in individual experiences [3]. Theory is developed as the result of the interpretation of the investigator in the research process under the meaning, experiences, events and the reality of the phenomenon being studied [7]. A theory can be defined as “a set of categories (concepts) that are systematically interrelated through statements of relationship to form a theoretical framework that explains some relevant social phenomenon” [3]. We identified two sets of core categories denominated “Institutional Context for Implementing SPI” and “Strategic Conduct in Implementing SPI” representing, respectively, the contextual factors that have influence on the success of a SPI initiative and the strategic actions taken by SPI implementation actors to reinforce or change such influences. Fig. 3 depicts the categories of each of these main categories that form the theoretical framework elaborated as part of this study.

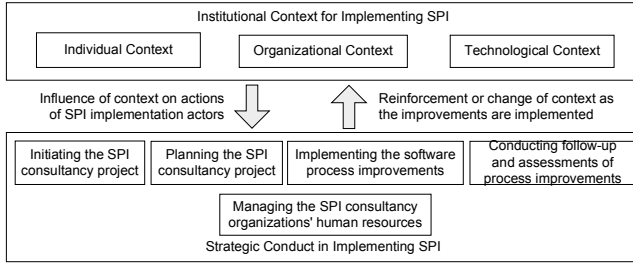


Figure 3. Process of Organizational Change Leading to Successful SPI Implementation Initiatives

We observed three types of institutional context categories: (i) individual, (ii) organizational, and (iii) technological. These contexts have different influence on the success of SPI initiatives. The actors of these initiatives react to these influences by taken different actions categorized in 5 different groups: (i) Initiating the SPI consultancy project, (ii) Planning the SPI consultancy project, (iii) Implementing the software process improvements, (iv) Conducting follow-up and assessments of process improvements, and (v) Managing the SPI consultancy organizations' human resources. The theoretical framework is explained in details in the following sections along with examples of the propositions extracted from the theory in support of the findings.

A. Institutional Context for Implementing SPI

The first core category aggregates the critical success factors in three categories. The concepts (attributes) of each category are presented in Table II.

TABLE II. CONCEPTS OF THE CONTEXT CATEGORIES

Category	Concept (Attribute)
Individual Context	Organization's members Higher management SPI consultancy organization's members
Organizational Context	Organizational strategies and policies SPI Program Environment
Technological Context	Software Process Software/Hardware Resources

a. From hereon, the concepts and its properties produced by the study are denoted in *italics*.

The influence that one or more concepts may have on the other is measured or perceived by the correlations between the dimensional variations of their properties. The study results show that the concepts of the individual, organizational and technological contexts have significant influence on each other. Fig. 4 depicts the relations between the concepts identified by the study.

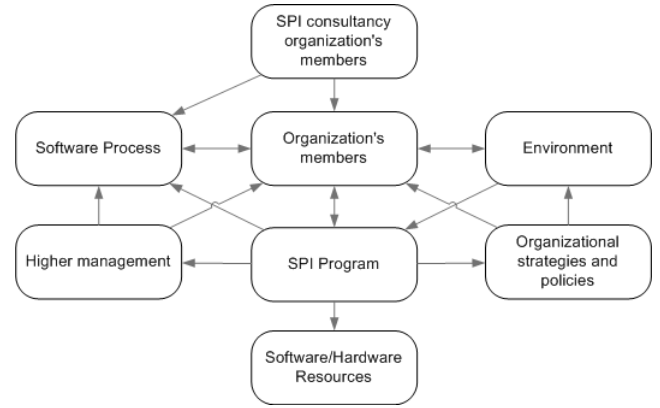


Figure 4. Representation of the inter-dependencies between concepts of the institutional context for implementing SPI.

In the following, we provide some descriptions of the properties that define each contextual concept and the dependency relationships on each other.

1) *Organization's members*: This is the contextual concept with higher density since it is composed of 17 different properties varying from *Commitment and involvement* to *Availability of time to dedicate to SPI activities*. Fig. 4 shows that the attitudes of *Organizations' members* toward implementing SPI suffer direct influence by practically all the relevant contextual concepts. This fact shows that one of the most critical aspects for the success of SPI resides in the reactions of the people that will execute the improvements throughout the organization and the projects. For instance, the study results show that *Motivation* and *Awareness of the SPI benefits* are properties of the *Organizations' members* concept that depend on the *Visibility of the SPI return on investment*, a property of the *SPI Program* concept. Moreover, our study results show that the attitudes of the *Higher management* also have influence on the *Organizations' members*. The coordinator of the consultancy organization noted that “when the higher management demands and supports [the

implementation of SPI] it is more likely to have acceptance of changes”.

2) *Higher management*: This concept is constituted of four properties (*Effective support*, *Trustfulness in the coordination of the SPI consultancy*, *Real perspective for process improvement* and *Influence in the organization*). Although this concept has lower density it has great influence in other concepts. One proposition extracted from the interviews shows how the influence of the *Higher management* attitudes can affect the *Complete SPI institutionalization*, a property of the *Software Process* concept: “When the higher management only wants to achieve the maturity level (even though they say that they want the process improvements), it is likely not to achieve institutionalization of the improvements”. Nonetheless, the study results show that there are some concepts that can affect the actions of the *Higher Management*, such as the *Visibility of the SPI return on investment*. The coordinator of the SPI consultancy noted: “the lack of visibility of intermediate results obtained with the implementation of process improvements can help to decrease the effective support of top management”.

3) *SPI consultancy organization's members*: This concept has influence on the attitudes of the *Organization's members*. The coordinator of the consultancy organization noted that “the lack of confidence of the organization's members in the consultants' knowledge can cause relationship problems”. Moreover, the study results also show that the attitudes of the *SPI consultancy organization's members* have influence on the adequacy of the *Software Process*. For instance, the *Competences* and *Flexibility* of the consultants can influence the *Adequate alignment of the processes implementation with the organization specificities*.

4) *Organizational Strategies and Policies*: One property of this concept is *Existence of acknowledgement policies to SPI collaboration*. The study results show that this specific property has influence in the *Environment*. The SPI implementation team members noted in the interviews: “when the work of the people involved in the SPI initiative is not acknowledged by the higher management, it is likely to have people turnover in the organization”. Nonetheless, the study results also show that the *SPI Program* results can have positive effect for realignment of the *Organizational strategies and policies* toward SPI implementation. For instance, the coordinator of the consultancy organization noted: “The positive result of the first formal process assessment may help overcome the problem of having the directors of the organization with conflicting objectives”.

5) *SPI Program*: We identified ten properties associated to this concept ranging from *Adequate management of the SPI program* to *Availability of human and financial resources*. The study results show that the attitudes of the people directly involved in the *SPI Program* can help overcome difficulties and barriers that affect other important concepts. For instance, the SPI managers and implementation team members noted that “monitoring in specific milestones of the SPI initiative

can help overcome the lack of visibility of intermediate results obtained with the implementation of process improvements”.

6) *Environment*: The environment concept is represented by seven properties ranging from the *Adequacy of the organizational structure* to *Internal/external events that may affect the organization*. As Fig. 4 shows, this concept has direct influence both on the *Organizations' members* and *SPI Program* concepts. For instance, global financial crises are external events that can affect the *Internal stability of the organization* and the *Constant flow of software projects* that are other two properties of the *Environment* concept. Moreover, these two properties can affect the *SPI Program* by provoking reduction in the availability of human and financial resources allocated to process improvements activities. One important lesson learned identified by the study is to observe the financial conditions of the organization before initiating a SPI implementation.

7) *Software Process*: The *Software Process* is the central concept of any SPI initiative and as a consequence has critical influence on its success. The study results show six properties related to this concept: *Alignment to strategic objectives*, *Adequacy of the processes/procedures definitions*, *Complete institutionalization of the improvements in the projects*, *Alignment to the organization specificities*, *Adequacy of SPI push-pull implementation relation*, and *Adequacy of process execution planning in the projects*. As Fig. 4 shows, the *Software Process* has a direct effect on the attitudes of the *Organizations' members*. More specifically, the study results show that the *Adequacy of process execution planning in the projects* can have direct influence on the *Availability of organizations' members' time to dedicate to SPI activities*. The coordinator of the consultancy organization noted: “when the schedules of the projects are done improperly without considering the activities of the improvement project and the normal learning curve, it is likely to have lack of organization's members' time for the SPI activities”.

8) *Software/Hardware Resources*: We identified three properties associated to this concept: *Adequacy of the supporting tools*, *Availability of software and hardware resources to support process execution*, and *Adequacy of the supporting tools selection process*. The study results show that the property *Availability of financial resources to SPI* of the *SPI Program* concept can affect the *Adequacy of the supporting tools*. The SPI managers and implementation team members noted that “when there is lack of financial resources, it is likely to have inadequate supporting tools”.

B. Strategic Conduct in Implementing SPI

The second core category of the theory is constituted of concepts and their respective attributes that represent the organizational change process and depict the interplay between SPI implementation key players and the institutional context leading to successful SPI initiatives. It is important to notice that these subprocesses and associated types of actions do not cover completely all the activities necessary to execute an SPI initiative, but it expresses the critical strategic actions that

should have special attention in order to maximize the chances to achieve success. This process is divided into 5 subprocesses described in the following:

1) *Initiating the SPI consultancy project*: Two types of actions were relevant in understanding the initial steps a SPI consultancy organization takes to successfully implement SPI (*Identifying the organizational context and the profile of the organization's members* and *Preparing the SPI consultancy contract*). The study results show that most of the critical success factors can be effectively addressed if appropriate actions are taken in the initial stages of an SPI initiative. Table III summarizes some of the theoretical propositions developed by the study that present the expected effects that actions taken by the SPI consultancy organization can have on the institutional context for implementing SPI. As the table shows, an SPI initiative starts by visiting the client organization aiming to meet the people and to exam the profile of the local team involved in the improvement project. From this knowledge it is possible to take more secure planning actions and to minimize project risks, for example, selecting a suitable consulting team, especially when the client is geographically distant from the SPI consultancy organization.

TABLE III. INITIATING THE SPI CONSULTANCY PROJECT

#	Examples of Propositions
1	In the first contact with the organization, understanding the organizational context and profile of the local team involved in the SPI initiative can help to select SPI consultants with adequate profile.
2	Examining the flow of projects planned for the period of the SPI initiative and not starting without the initial warranty of projects needed to complete the SPI initiative on schedule will help prevent the failure of the SPI initiative or increase in the schedule due to lack of projects.
3	Making flexible contracts, explaining to the organization that it is not possible to know at first exactly what is needed, helps avoid the problem of consulting hours defined a priori disregarding the organization's needs.

2) *Planning the SPI consultancy project*: We identified four types of actions that are relevant to be considered in the planning of a SPI consultancy project (*Defining the strategy for processes definition*, *Defining the strategy for introducing process changes*, *Defining the software and hardware resources to support the software processes*, and *Defining the organization of the SPI initiative*). The objective of this type of actions is to answer the following questions: *how processes are going to be defined?*, *how improvements are going to be introduced in the organization?*, *who will be involved in the implementation?*, *what are the required capabilities to effectively implement SPI?*, *what are the mechanisms for acquiring the necessary expertise to effectively implement SPI?*, *what are the projects that will be directly affected by the implementation?*. By addressing these questions appropriately, a SPI consultancy organization can significantly maximize the success chances of the SPI initiatives. Table IV summarizes some of the theoretical propositions that support these findings. As Table IV shows the SPI consultancy organization

can be a catalyst of the improvement cycle by helping to rapidly define software processes and to facilitate its use and continuous improvement based on its evaluation after the execution on each of the software projects. Another important strategic action promoted by the SPI consultancy organizations is to provide adequate involvement of relevant stakeholders during the initial steps of the improvement cycles where the most critical decisions are taken, such as the selection of the supporting tools and the initial definition of the processes.

TABLE IV. PLANNING THE SPI CONSULTANCY PROJECT

#	Examples of Propositions
4	Making a diagnosis of the organization, the actual practices and the knowledge and skills of the team helps to support the decision of the maturity level that can be appropriately pursued and the necessary time for this. Moreover it helps to overcome the problem of directors that want to achieve a maturity level too high for the possibilities of the organization and the team.
5	Introducing changes gradually helps to have an appropriate balance between the improvements required by higher management, the needs of the adopted models and the improvements proposed by organization's members.
6	Generating an initial version of the process rapidly, using and improving it continuously by evaluating the process on each project, helps to have an appropriate balance between the improvements required by higher management, the needs of the adopted models and the improvements proposed by organization's members.
7	Respecting the actual team work practices and organizational culture, using as much as possible what exists in the company, helps to have an appropriate balance between the improvements required by higher management, the needs of the adopted models and the improvements proposed by the organization's members.
8	Supporting the organization in selecting the adequate tools in terms of cost and features can help the organization.
9	Supporting the planning of involvement and communication with members of the organization can help overcome problems of lack of involvement of members of the organization in the SPI initiative.

3) *Implementing the software process improvements*: Four relevant types of actions were identified in understanding how a SPI consultancy organization can effectively support the implementation of SPI (*Recommending the adoption of mechanisms to manage human resources*, *Conducting trainings*, *Executing actions for achieving consciousness for process improvement*, and *Supporting the execution of SPI implementation actions*). We could observe that the SPI consultancy organization poses a critical role in the success of the SPI project because it functions as a facilitator of the SPI implementation providing knowledge transference and adequate communication information across different organizational levels. Moreover, the consultancy organization has important role in specific contexts where the clients do not provide the adequate resources for execution of the SPI actions. Table V summarizes some of the theoretical propositions that show how an SPI consultancy organization can facilitate the practical implementation of process improvements.

TABLE V. IMPLEMENTING THE SOFTWARE PROCESS IMPROVEMENTS

#	Examples of Propositions
10	Recommending the establishment of a program for promoting trainings and professional development can help overcome the problem of the organization without members with appropriate expertise in software engineering. However, the return of such programs generally occurs in the medium and long term.
11	Providing specific training for the improvement to be implemented and the execution of the processes can help overcome the problem of the organization's members without adequate competences.
12	Explaining the potential benefits for the career of each organization's member and how process improvement will help improve the work in the company and organize its own work can help overcome the problem of lack of interest or motivation of the organization's members by the SPI initiative.
13	Allocating people to perform consulting roles required by the implementation of process improvements can help overcome the problems of unavailability of qualified members of the client and without time to improvement activities. However, this is not positive in the long term, because it makes the organization dependent on the knowledge of the SPI consultancy organization.

4) *Conducting follow-up and assessments of process improvements*: Three types of actions were identified to explain how a SPI consultancy organization can help to keep the SPI project on the track (*Conducting follow-up of the process improvements*, *Overcoming critical barriers for the SPI implementation*, *Communicating the achieved SPI implementation results*, and *Controlling the implementation of process improvements*). The SPI consultancy organization can help to promote the SPI implementation initiative across the organization by making visible the achieved results to all the different organizational levels. Moreover, the external position of the consultancy organization in the SPI initiative facilitates taking actions to overcome critical barriers that can jeopardize its success. Since the main theme of the investigation study was on critical success factors, we observed a high number of evidences of types of actions to overcome barriers associated to those factors. Table VI summarizes the theoretical propositions that support these findings.

TABLE VI. CONDUCTING FOLLOW-UP AND ASSESSMENTS OF PROCESS IMPROVEMENTS

#	Examples of Propositions
14	Conducting meetings with the organization's members at the end of each software project to identify opportunities for improvement helps overcome the problem of the organization not perceiving benefits in the process improvements after some project closures.
15	Performing assessments at the end of each project to see if improvements have been obtained and to identify new opportunities for improvement can help organization's members perceive improvements in their work obtained as a result of the SPI initiative.
16	Trying to demonstrate the benefits of process improvement with measures (indicators) can help overcome the problem of the organization's directors interested only in the achievement of the maturity level in disregard of the process improvements.
17	Demonstrating the return on investment from the process improvement in other organizations helps to overcome the problem of lack of support and commitment of higher management in the SPI initiative.

5) *Managing the SPI consultancy organizations' human resources*: Since this study investigated SPI implementation in the perspective of a SPI consultancy organization, we could observe some actions taken internally of the consultancy organization that have influence on SPI initiatives success. Basically these actions are related to one type of action named *Capacitating the SPI consultancy organizations' human resources*. Table VII summarizes the theoretical propositions that show how an SPI consultancy organization can improve the competences of their consultants.

TABLE VII. MANAGING THE SPI CONSULTANCY ORGANIZATIONS' HUMAN RESOURCES

#	Examples of Propositions
18	To ensure knowledge, skills and experience to the team it is important that the consultancy organization has a policy of training and continuing education.
19	Having an adequate selection process helps to have SPI consultants with adequate competences and experiences.
20	Requiring comprehensive study activities and training before working in SPI consultancy projects helps to form SPI consultants with adequate competences and experiences.

VI. DISCUSSION

A. Contributions

In order to indicate the contributions, we considered the following criteria to verify if the grounded theory developed is well formed given the context and scope of the study [4][6]:

- **Fit**: The theory must fit with the substantive research area and corresponds to the data.
- **Understanding**: The theory makes sense to practitioners in the study area.
- **Generality**: The theory must be sufficiently abstract to be a general guide without losing its relevance.
- **Control**: The theory acts as a general guide and enables the person to fully understand the situation.

We are confident that the data and analysis fit with the criteria above. During the research process, we avoided the identification of categorizes based on the investigators own ideals and perceptions. Since the primary data for elaborating the propositions that form the basis of the theory were collected from multiple sources (surveys, literature reviews and interviews), we applied the constant comparative method aiming to look for multiple incidents of data in the different data sources. Therefore, we can attest that the theoretical *fitness* is maintained.

In order to guarantee that the theory is *understandable* to SPI practitioners we conducted a survey involving the coordinators of different SPI consultancy organizations. These organizations were selected from the community of practice on the Brazilian software process model named MR-MPS [13]. The MR-MPS model is conformant to ISO/IEC 15504 standard and adherent to CMMI-DEV model [15]. The regulator organization of this model is the SOFTEx, a private not-for-profit organization created to promote Brazilian software

industry competitiveness. SPI consultancy organizations accredited by SOFTEX to implement the MR-MPS model are named Implementation Institutions.

In Brazil, there are 18 Implementation Institutions accredited by SOFTEX. We send a questionnaire to each of the coordinators of these institutions with a list of propositions that form the basis of the developed theory. Each proposition was assessed by the coordinators in a three point scale (1-“I do not agree with the proposition”, 2-“I agree partially with the proposition” and 3-“I do agree with the proposition”). 12 out of the 18 coordinators responded the survey, representing more than 66% of the total population. Therefore, we can consider the responses as representative of the Brazilian SPI consultancy organizations. After performing basic descriptive statistics of the data, we concluded the following:

- 78% of the propositions were agreed by all the experienced SPI consultancy coordinators (level of confidence of 95% by applying one sample t-test technique).
- None of the propositions were refuted by all the coordinators.

The results of the survey with the SPI consultancy coordinators show that the theory is understandable and makes sense to them. The propositions agreed by all the experienced SPI consultancy coordinators constitute the general theory for implementing SPI. The remaining propositions represent individual perspectives of the SPI consultancy organizations and, as a consequence, constitute specific theories for implementing SPI. The discussion of the theory presented in the last sections is based only on the propositions of the general theory, because we considered that they are more representative of the SPI implementation phenomenon based on the study results.

The Implementation Institutions accredited by SOFTEX are obligated to elaborate two reports per year with the lessons learned and best practices of implementing SPI. In order to assess the *generality* criteria of the theory, we verified the occurrence of the categories that form the theory in those reports. In total, we analyzed 85 reports elaborated by 15 different Implementation Institutions during a 5 year period (from 2005 to 2009). The results of this analysis are the following:

- 76% of the properties of the contextual concepts were verified in the reports.
- 85% of the actions of the behavioral categories were verified in the reports.

Although we could not verify the occurrence of all the categories, the results are significant. Therefore, we can attest with confidence that the theory is sufficiently abstract to accommodate the perspectives of different SPI consultancy organizations with varied experiences in conducting SPI initiatives. Since the theory was elaborated from the interviews with COPPE/UFRJ SPI consultants, we did not analyze its reports aiming to avoid the bias of the analysis.

According to Coleman and O'Connor [4], the *control* criteria of a theory can be assessed by verifying that the developed theory provides a sufficient number of categories and concepts and explains the relationship between them. Therefore, we can attest that the categories, concepts and propositions of the theory developed in this study are sufficient to allow SPI practitioners not only to be able to understand and analyze situations, but also to predict change and its consequences and to be capable of revising his/her actions, if necessary.

B. Implications for SPI Research

The theoretical framework presented in this paper suggests that the success of SPI initiatives depends on an inter-related set of individual, organizational and technological conceptual properties. Moreover, the study results demonstrated that such relationships are changed and reinforced by the actions/interaction of SPI key players. These results have some implications in the SPI research. For instance, SPI researches can develop specific instruments to quantitatively measure the presence or absence of critical success factors properties, thus facilitating the analysis of the conditions for conducting SPI initiatives. Nonetheless, further empirical validation and elaboration of the contextual concepts is required based on the application of the theory in SPI initiatives conducted by different SPI consultancy organizations.

C. Implications for SPI Practice

There are also some implications for the SPI practice. The theoretical framework can help SPI practitioners to understand the direct and indirect causes of SPI initiatives failures and successes. SPI consultancy organizations can use this knowledge to elaborate more efficient risk management strategies based on information about previous SPI initiatives coordinated by the organization.

The theoretical knowledge can also provide guidance for SPI consultants to develop effective SPI implementation plans. For instance, the critical success factors properties can be used as a checklist to determine the viability of conducting a SPI initiative under specific circumstances. Moreover, the behavioral types of actions can be used to determine the readiness of SPI consultancy team members to participate on SPI projects.

D. Limitations of the Study

There are some limitations of the study. The theoretical framework describes the context and organizational change process that organizations may experience during SPI implementation. Nonetheless, it is important to notice that the relationships presented are not deterministic. Organizational changes provoked by SPI implementation not always will be the intended by the key-actors of the underlying phenomenon. For instance, the coordinator of an SPI initiative may have performed adequate planning of the SPI initiative in terms of schedule and resources and still experience difficulties in the institutionalization of the software processes in the projects due to other factors such as reduction of team productivity as a consequence of the learning curve in the introduction of software development innovative practices.

The theoretical framework was also developed based on the external view of SPI consultants. Therefore, the presented results do not address the perspective of important key players of SPI initiatives such as software organizations' members. Moreover, the framework was not validated in other contexts, thus the capability of generalization of the results is limited.

VII. CONCLUSIONS

This work presented the results of the application of Grounded Theory methodology to support the construction of a theory for implementing SPI based on the individual experiences of SPI consultants of a consultancy organization. So far, we have accomplished significant contributions. Firstly, we demonstrated the applicability of Grounded Theory to support investigations about SPI implementation. Moreover, we developed a theoretical framework that explains: (i) the contextual factors that have either positive or negative influence on the success of SPI initiatives, and (ii) the strategic actions representing the interplay between SPI implementation key players and the institutional context leading to successful SPI initiatives.

We also assessed the study results and concluded that the theory developed fits with the substantive research area and corresponds to the data, makes sense to SPI practitioners, is sufficiently abstract to be a general guide without losing its relevance, and it enables SPI practitioners to fully understand the situation concerning SPI initiatives.

This framework is currently being used to execute more investigations about how consultancy organizations can develop more efficient implementation strategies aiming to give a more practical use of the theory for SPI practitioners.

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