A Method Framework for Engineering Process Capability Models

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Abstract
Software Process Improvement, based on a Maturity Level or a Process Capability Profile, from a capability maturity model or an ISO/IEC 15504-based model, is well established in the software industry as a successful mean for improving software intensive organizations. In consequence there is an opportunity to understand how these models have been developed and consolidate this knowledge to support the development of new models by, among others, the industry. This article introduces a Method Framework for Engineering Process Capability Models as an element of a methodology on a Process Capability Profile to drive Process Improvement. This method framework is based on five previous successful experiences in which we experiment different processes to develop different process capability models. The current version is composed of sequential practices, customization rules, examples of utilization and examples of techniques. An initial validation indicates a first confidence that this method framework is a useful proposal for developing methods and processes for engineering process capability models.

Keywords
Software Process Improvement (SPI), Process Capability Model, PRO2PI Methodology, CMMI, ISO/IEC 15504
1 Introduction

Around the 1980’s, Watts Humphrey and others at the Software Engineering Institute (SEI) elicited and generalized good practices from few software intensive organizations that had been working well. Those practices were organized as sequential and cumulative maturity level as the Capability Maturity Model for Software (CMM or SW-CMM) [1]. With the success of CMM as practical guidelines for a feasible practical improvement of software intensive organizations, a new area emerged: Software Process Improvement (SPI). As an evolution of CMM two frameworks of models were established: ISO/IEC 15504 International Standard for Process Assessment [6] and the Capability Maturity Model Integration (CMMI) [2]. CMMI is aligned with ISO/IEC 15504 and the CMMI-DEV model [2] is the successor of CMM.

Basically the current SPI area continues the same as it was established around CMM and the CMMI-DEV is the dominant model, although ISO/IEC 15504-based models are relevant too. There are, however, forces around the successful current SPI that urge for a revision and evolution of SPI area [3, 4]. One of these forces is related with the need to develop more process capability models. Therefore there is an opportunity to understand how process capability models have been developed and consolidate this knowledge to support the development of new models. The industry will participate more in this development, as models for more specific business context, for more specific domain or even for a specific organization will be develop as customization of relevant more generic models.

The term Process Capability Model [5] is used to mean models of best practices organized with the concepts of process capability and process maturity. In this sense a capability maturity model, as, for example, the CMMI-DEV model [2], is a process capability model. An ISO/IEC Process Assessment Model, as, for example, the ISO/IEC 15504-5 model [6], is a process capability model as well.

In order to support the development of new models, this article introduces PRO2PI-MFMOD as a “Method Framework for Engineering Process Capability Models as an element of the PRO2PI Methodology”. PRO2PI is a methodology on “Process Capability Profile to drive Process Improvement” [3, 4]. PRO2PI is an exemplar methodology for a proposed evolution of current SPI area, named MDPEK: “(Process Capability Profile) Model-Driven (Process Capability Engineering) for (Software, System and other Knowledge Working) Intensive Organization” [3].

The initial objective was to develop a method. During the construction, we realize that the variety of situations, however, raised significant risks to develop a single method. Therefore, we decided to develop a more abstract methodological element to support the definition of methods. We developed a Method Framework. This term is already used with similar meaning, similar objective and similar reasons for the Method Framework for Engineering System Architectures (MFESA) [16] which confirms the usage of this term within this context. The major difference from the meaning of method framework is that PRO2PI-MFMOD does not define the contextual elements because these elements are already provided by the PRO2PI methodology.

This article is organized as follows. This first section provides an introduction to the article. The second section digests the PRO2PI Methodology. The third section establishes goals, methodology and process for the development of this method framework. The fourth section reviews previous experiences in developing models. The fifth section introduces the PRO2PI-MFMOD. The sixth section presents how those processes can be considered as examples of the method framework. The seventh section describes how the method framework is planning to be used for a complex system. Finally, the eighth section presents some initial validation and some conclusions.

2 PRO2PI Methodology

PRO2PI is a multi-model process improvement methodology driven by process capability profiles. As an exemplar methodology for MDPEK, PRO2PI supports process improvement using elements from multiple reference models and other sources. These elements are selected or defined and they are integrated as process capability profile. A process capability profile that drives a process improvement under PRO2PI methodology is also named as a PRO2PI. Figure 1 presents the conceptual elements
of the PRO2PI methodology, the relationship among them and the name of each one.

PRO2PI-SMOD is a sustainable model for the dissemination and evolution of PRO2PI methodology. PRO2PI-REPO is a repository for PRO2PI assets. PRO2PI-MMOD is a metamodel for a process capability profile and process capability model. Using PRO2PI-MMOD, PRO2PI-EUMOD1 is an exemplar unified process capability model with elements from selected relevant models, and PRO2PI-EN1 is a notation to represent a PRO2PI. PRO2PI-PROP is a set of properties for a PRO2PI. PRO2PI-MEAS is a set of measures to qualify a PRO2PI. PRO2PI-CYCLE is a process for process improvement cycles including a function to define, update or use a PRO2PI.

PRO2PI-WORK is a method for a workshop to establish a process capability profile to drive a process improvement cycle. This method was developed to guide the implementation of the first three phases of PRO2PI-CYCLE in a low capability, small organization. In addition, two customized variations of this method were defined. PRO2PI-WORK4A is a method for a workshop with emphasis in the assessment of current practices and PRO2PI-WORK4E is a method for a workshop with emphasis in education on process improvement. PRO2PI-MFMOD is a method framework for engineering process capability models that is described in this article.

3 Goals, Methodology and Process

This section establishes a main general goal, three derived objective goals, the methodology and the process used to guide the development of the method framework. The main general goal is that the method framework is a useful proposal for developing methods and processes for engineering Process capability models. The first objective goal (Goal G1) is that the method framework could be considered as a generalization of a given set of processes and methods used to successfully develop process capability models. The second objective goal (Goal G2) is that it is part of the PRO2PI methodology [3, 4] because developing models is part of the scope of this methodology. The third unfolded goal (Goal G3) is that it supports the planning for a process to develop a model for best practices in a given complex system.

The development of this method framework followed the process capability levels form ISO/IEC 15504 as a methodology [6]. First we participated and studied successful processes to develop models in order to construct knowledge about developing models. This is related with capability level 1 for a “process capability model engineering” process area. Then we planned, performed, monitored and controlled five successful processes to develop five different process capability models. This is related
with capability level 2 for this same process area. The development of this method framework from an analysis of these five previous successful experiences in model development prepare for capability level 3. The engineering of a process capability model will be guided by a planned, performed, monitored and controlled defined process that is tailored from the method framework. Therefore, the defined process will be a capability level 3 process.

Using this methodology, a process was planned and performed with the following seven activities to develop the method framework presented in this article: (1) preparation for the work; (2) identification and initial analyses of previous experience from our research group and from others groups; (3) revision of PRO2PI methodology to include the method framework; (4) development of a preliminary version of the method framework; (5) more disciplined revision of the previous experiences identifying including a relationship between the process used in each previous experience with the preliminary method framework; (6) revision of the method framework in such way that all previous experiences could be considered as examples of instantiation of this method framework; and (7) usage of the method framework to plan a process to develop a process capability model for a complex system.

4 Structured review of previous experiences

This section reviews five previous successful experiences in which we experiment different processes to develop different process capability models. In addition four more experiences from others are presented. We also participated in some of these experiences from others. For each one of these nine experiences a structured review is presented with a phrase name (in bold type), a brief description, the activities of the actual planned and performed process used to develop the model, and examples of techniques used to develop the model.

Process for a model for education: This model was composed of a new process area to cover the teaching of a technical course [7]. This process area is defined as a new process for the ISO/IEC 15504-5 model. The strategy was to abstract a process area from the current process used by the teacher. For the development of this process capability model for education, a process with the following seven activities was defined and used: (1) description of the current process used by the teacher; (2) analyses of the guidelines defined by the organization; (3) description of an improved process, following the ISO/IEC 15504-5 model, to be used by the teacher; (4) definition of a new process area for ISO/IEC 15504-5 such that improved process is an exemplar implementation; (5) assessment of the current process; and (6) revision and consolidation of the new process area. A specific technique predefined for this process is to abstract a process area from an actual process.

Process for the MARES model: A specialization of the ISO/IEC 15504-5 model for Small and Medium Enterprises (SME) was developed as part of a project to develop a Method for Process Assessment in Small Software Companies (MARES) [8]. A process for the MARES Model, with seven activities, was planned and followed: (1) state of the art of process improvement in SME review and study of ISO/IEC 15504-5; (2) state of the art of methods and models for SPI in SME; (3) requirements definition for the proposed model; (4) development of a draft model; (5) evaluation through four case studies using the draft model; (6) revised draft model; and (7) evaluation through two new case studies. Two specific techniques predefined for this process are state of the art literature review to gain knowledge and case studies to validate a draft model.

Process for a CMMI specialization to CBSE: For a development of a process capability model for Component Based Software Engineering (CBSE) a process was defined and used [9]. The eight activities of this process are as follows: (1) review the state of the art and state of the practice, in this case, for CBSE, (2) identify a process capability model more appropriate to be specialized for the domain (in this case CBSE), (3) identify or define a set of additional process areas to cover the major CBSE specific aspects, (4) represent these new process areas using the format of the base model, (5) identify process areas from the base model that needs customizations for CBSE and perform those customizations (6) identify other generic process areas from other relevant models that are relevant for the domain and include them in the model, (7) consider practices from relevant organization that already implement good CBSE, include those practices as additional sources, and revise the model to cover these practices, and (8) use the model in CBSE organizations, analyse the results and revise the model. A specific technique predefined for this process is to translate process areas from a given
model (in this case the ISO/IEC 15504-5 model) to new process areas for another model (in this case the CMMI-DEV model).

**Process for a CMMI specialization to banking domain:** In the development of a specialization of the CMMI-DEV process capability model for software development in the banking domain [10], a process for a CMMI model specialization was defined and used with the following seven activities: (1) characterization of the domain, (2) selection of some process areas, (3) initial description of the domain, (4) exploration of the domain description and specialization of the selected process areas, (5) revision of the domain description and the process areas specialization, (6) validation; and (7) revision and consolidation. A specific technique predefined for this process is to describe a domain using phrases and to relate them to some practices of a model in order to determine if a practice from a model has higher, same or less relevance for that domain.

**Process for the SPICE for Research model:** For developing an ISO/IEC 15504-based process capability model for University Research Laboratory (SPICE for Research Model) [11, 12] a process was defined and used for the construction of this model. The six activities of this process are as follows: (1) state of the art review, (2) best practices survey, (3) process capability model draft design, (4) process capability model draft development, (5) process capability model validation, and (6) process capability model version 1.0. University Research Laboratory (URLab) is a unique environment that performs knowledge-intensive activities. The SPICE for Research considers the best practices investigated in some URLabs and the technical and scientific literature on knowledge management, research management, organizational management, and capability models. Two different communities validated SPICE for Research: the community of managers of research and the community of researchers with experience in process improvement [12]. Two specific techniques predefined for this process are using questionnaires to obtain information from experts in the domain and performing extensive literature review to understand best practices for the domain.

**Generic process for consolidated models:** There are a set of process capability models that can be considered as more relevant and more consolidated models, including the original SW-CMM model, CMMI models (CMMI-DEV, CMMI-SRV and CMMI-ACQ), ISO/IEC 15504 models (ISO/IEC 15504-5 and ISO/IEC 15504-6), other ISO/IEC conformant models (OOSPICE, Automotive SPICE, Enterprise SPICE and others), the e-SCM models, the MPS.BR model and the COMPETISOFT model. For neither one of them, we could found a complete documented process about how each one was developed. There are only general information about the development, as, for example, the ISO rules and procedures to develop an International Standard. Up to now, we did not produce activities for the process used to develop these models.

**Process for a leadership model:** In a development of a process capability model for leadership of Integrated Virtual Teams, Tuffley [13] defined and used a process with the following five activities: (1) literature review; (2) process capability model draft development; (3) cases study using the draft model (4) results analyses and (5) model consolidation (with possible cycles of activities 2, 3 and 4).

**Process for models from requirements transformation:** Barafort et al. proposed a method to transform a set of requirements into a process capability model [14]. They followed this method to develop a process capability model for IT Service Management from the ISO 20000 requirements. This method has the following nine activities: “(1) identify elementary requirements in a collection of requirements, (2) organize and structure the requirements, (3) identify common purposes upon those requirements and organize them towards domain goals, (4) identify and factorize outcomes from the common purposes and attach them to the related goals, (5) group activities together under a practice and attach it to the related outcomes, (6) allocate each practice to a specific capability level, (7) phrase outcomes and process purpose, (8) phrase the base practices attached to outcomes, and (9) determine work products among the inputs and outputs of the practices” [14].

**Process for a model for SaaS:** Cancian developed a draft process capability model as a reference guide for assessing software development process practiced by SaaS (Software as a Service) providers [15]. In order to accomplish its objectives, quality requirements that providers should meet were elicited. After having been summarized and analyzed, the requirements were mapped to existing standards and reference models. From this mapping, a reference guide was proposed. A process was defined and used for the construction of this draft model, with the following five activities: (1) literature review, (2) gathering of requirements, (3) complementation and determination of the priority among those requirements, (4) mapping of those requirements, and (5) construction of the reference guide.
5 PRO2PI-MFMOD Method Framework

PRO2PI-MFMOD is a method framework for engineering process capability models based on context and characteristics of a segment or domain. The current version is composed of four types of elements, each one, by a coincidence, with seven elements: sequential practices, customization rules, examples of utilization and examples of techniques. The examples of utilization and examples of techniques are described in Section 4. The sequential practices and customization rules are described in this section.

PRO2PI-MFMOD defines seven sequential practices to guide the development of a method or a process to develop a process capability model: (1) initial decisions, (2) sources analysis, (3) strategy for development, (4) model design, (5) draft model development, (6) draft model validation, and (7) model consolidation (Figure 2).

![Figure 2- PRO2PI-MFMOD’s seven sequential practices](image)

The first practice of PRO2PI-MFMOD is related with some initial decisions after a decision and commitment for model development. These initial decisions can be related with any one of the following six practices. In the second practice (Sources analysis) we identified, gather and analysed sources for good practices. These sources can include literature review, surveys, and others. These sources are based on the context and characteristics of a segment or domain. The third practice (Strategy for development) is related with the definition of the strategy to be used to develop the model. One key issue is how the community of interest will be involved in this development. Another issue is using selected good practices from process capability models (SW-CMM, ISO/IEC 15504-5, iCMM, CMMI-DEV, OPM3, COBIT, eSCM-SP/CL, MR-MPS, COMPETISOFT, ...), other reference models (ISO 9001, PMBOK, ISO/IEC 12207, SWEBOK, EFQM, PNQ, RUP, ...) and/or any other sources.

The fourth practice (Model design) is related with the design of the process capability model. ISO/IEC 15504 establish as general structure for model design as Process Reference Model and Process Assessment Model. PRO2PI-MMOD as a metamodel provides a reference for this design. The fifth practice is the draft model development. The sixth practice is the validation of the draft model. The seventh practice is the consolidation of the process capability model.

As part of the method framework, these seven sequential practices must be customized as activities of a method or even by a process. This customization is oriented by combinations of seven simple cus-
tomization rules (CR1 to CR7). These seven customization rules are described as follows, in terms of the relationship between one or more method framework’s practice and one or more method or process’s activity:

CR1: A practice corresponds to an activity (one practice to one activity);

CR2: There is no activity that corresponds to a practice, because the results to be produced by the practice execution are already predefined by the method or process (one practice to zero activity);

CR3: There are no activities that correspond to one or more consecutives final practices, because the life cycle of the method or process ends before those final practices (many final practices to zero activity);

CR4: Two or more activities correspond to one practice, because the activities are more detailed customization of the practice (one practice to many activities);

CR5: An activity corresponds to two or more consecutives practices, because the activity is a more general and simplified customization of the practices (many practices to one activity);

CR6: There are consecutive activities that correspond to cycles of consecutive practices (many practices to activity cycles); and

CR7: There is one or more technique that is specified for one or more activities.

The next provides representations of those processes (described in Section 4) as customizations of the method framework and explain these customizations in terms of applications of these customizations rules. In this way, the next section supports the understanding of these customizations rules.

### 6 Processes and PRO2PI-MFMOD

Table 1 show the PRO2PI-MFMOD’s seven practices and the activities of each one of the five processes described in Section 4 and indicate how each practice is related with the activities.

**Table 1 – practices of PRO2PI-MFMOD and activities of five processes**

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The process for a model for education customizes the method framework applying the following customization rules: (a) rule CR2 is applied related with practice 1 because the initial decisions were already taken before the process was defined; (b) rule CR4 is applied because the activities 1, 2 and 3 are more detailed than the correspondent practice 2; (c) rule CR5 is applied because the activity 4 is more general and simple than the correspondent practices 3, 4 and 5; (d) rule CR4 is applied again because the activities 5 and 6 are more detailed than the correspondent practice 6; and (e) rule CR7 is applied because the process finished with the validation of the model draft version, and then there is no activity that correspond to the final practice 7.
The process for the MARES mode customizes the method framework applying the following customization rules: (a) rule CR2 is applied related with practice 1 because the initial decisions were already taken before the process was defined; (b) rule CR4 is applied because the activities 1 and 2 are more detailed than the correspondent practice 2; (c) rule CR1 is applied because the activity 3 corresponds to practice 3; (d) rule CR5 is applied because the activity 4 is more general and simple than the correspondent practices 4 and 5; (e) rule CR1 is applied because the activity 5 corresponds to practice 6; and (f) rule CR4 is applied again because the activities 6 and 7 are more detailed than the correspondent practice 7.

The process for a CMMI specialization to CBSE customizes the method framework applying the following customization rules: (a) rule CR2 is applied related with practice 1 because the initial decisions were already taken before the process was defined; (b) rule CR1 is applied four times because each one of the activities 1, 2, 3 and 4 corresponds to the practices 2, 3, 4 and 5; (c) rule CR5 is applied four times because each one of the activities 5, 6, 7 and 8 is more general and simple than the correspondent consecutives practices (3 and 4), (3 and 4 again), (2, 3, 4 and 5), and (6 and 7); (d) rule CR6 is applied three times because each one of the activities 5, 6, and 7 are cycles: activity 5 repeats practices 3 and 4, activity 6 repeats practices 3 and 4 again and activity 7 repeats practices 1, 2, 3 and 4.

The process for a CMMI specialization to banking domain customizes the method framework applying the following customization rules: (a) rule CR2 is applied related with practice 1 because the initial decisions were already taken before the process was defined; (b) rule CR1 is applied because the activity 1 corresponds to practice 2; (c) rule CR2 is applied for the no correspond activity for practice 3 because the strategy for the development (the result of practice 3) was already defined before the process; (d) rule CR4 is applied two times because each one of the consecutive activities (2 and 3) and (4 and 5) corresponds to the practices 4 and 5 respectively; and (e) rule CR1 is applied four times because each one of the activities 6 and 7 correspondents to practices 6 and 7 respectively.

The process for SPICE for Research customizes the method framework applying the following customization rules: (a) rule CR2 is applied related with practice 1 because the initial decisions were already taken before the process was defined; (b) rule CR4 is applied because the activities 1 and 2 are more detailed than the correspondent practice 2; (c) rule CR2 is applied for the no correspond activity for practice 3 because the strategy for the development (the result of practice 3) was already defined before the process; and (d) rule CR1 is applied four times because each one of the activities 3, 4, 5 and 6 correspondents to practices 4, 5, 6 and 7 respectively.

Table 2 shows the PRO2PI-MFMODE’s seven practices and the activities of each one of the four other processes described in Section 4 and indicate how each activity is related with the practices. For the generic process for consolidated models, we estimate a general process as cycles of PRO2PI-MFMODE’s seven activities.

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7 Using the Method Framework for a Complex System

This session introduces the issues of application of this method framework for building process capability models in the context of complex systems. There is no consensus on the definition of complexity in the literature [18]. In the functionalist sense of the word, complexity refers to a large set of variables...
whose relations cannot be mapped or monitored [18]. For Demo [19], complexity is linked not only with the number of variables, but with a set of properties for interpreting a phenomenon as complex. The properties highlighted by the author are: the dynamics, the ambiguity, and the non-linearity. What is totally predictable and linear is not complex. These properties above help to characterize the complex phenomenon as complex. The complex system in focus here is the Brazilian Public Software (SPB after the Portuguese name: Software Público Brasileiro) [17].

The concept of public software in Brazil has its first public records of discussion in the 90’s [17]. The first experiments supported conceptual nuances that had different scales, ranging from the software to be shared only in the public sector to the total release to society. In 1995 the state computing companies, captained by ABEP, began a process of discussion on what later became the concept of SPB [17]. At that time the intention was to accelerate cooperation in the government, in order to reduce developmental efforts, assign costs and rationalize resources. The trend for the total release of solutions to society is recent. Their format comes from the experience of the federal government.

A one year project is under way to consolidate a technical framework for SPB. One part of this project is a subproject to identify and consolidate, as process capability models, best practices for developing and evolve software or services and best practices to perform a service. This subproject has three sequential phases: (Phase 1) consolidation of this method framework and understanding of the SPB; (Phase 2) development of a draft version of the model; and (Phase 3) validation and consolidation of an initial version of the model. Phase 1 is already complete and Phases 2 and 3 are planned as an instantiation of this method framework.

This instantiation is composed of fourteen activities: (1) initial decisions; (2) sources identifications and initial analyses; (3) strategy for development; (4) detailed analyses of the identified sources; (5) detailed of the strategy; (6) high level model design; (7) revision of sources and new analyses; (8) revision of the strategy; (9) model design; (10) draft model development; (11) initial validation; (12) draft model development; (13) validation; (14) model consolidation. Table 3 shows the activities of this planned process and relate them with the practices of the method framework as applications of the customization rules.

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### 8 Initial Validation and Conclusion

Although this is a work in progress, the achievement of the three unfolded objective goals is commented as an initial validation. The achievement of Goal G1 is evidenced by Tables 1 and 2 showing that the activities of each one of the nine identified processes can be expressed with applications of the seven customizations rules on the seven PRO2PI-MFMOD’s practices. The achievement of Goal G2 is evidenced by Figure 1 showing PRO2PI-MFMOD as one element of PRO2PI methodology. Finally the achievement of Goal G3 is evidenced by Table 3 showing that the activities of the planned process for engineering a process capability model for SPB complex system can be expressed with applications of the seven customizations rules on the seven practices of PRO2PI-MFMOD.

This article introduced PRO2PI-MFMOD as a Method Framework for Engineering Process Capability Models. This method framework supports the definition of methods or processes to engineer a process capability model. The achievement of the three derived objective goals indicates a first confidence that PRO2PI-MFMOD is going to be a useful proposal for developing methods and processes for engineering process capability models.
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Literature

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