Reference Model for Software Process Improvement: A Brazilian Experience

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Abstract. Recent research efforts about quality in the software area demonstrate that a concentrated effort is necessary to improve software process. Mainly in Brazil, there is an urge to enhance software processes performance aiming to improve the quality of software products and to increase Brazilian organizations competitive advantages both in the national and international markets. This work describes an approach developed to establish the base for Brazilian organizations to improve software processes. The focus of this work is to increase the software development capability of small and medium size companies in a fast pace. The presented approach consists of the development of a Reference Model for software process improvement and an appraisal method for the Brazilian software industry. This model has been deployed in several Brazilian companies thorough the support of Software Development Environments. The pilot experience and empirical validation results of application of the presented approach are also described in this paper.

1 Introduction

Recent research efforts about quality in the software area demonstrate that a concentrated effort is imperative to improve software process in software development companies [1]. Mainly in Brazil, there is an urge to enhance software processes performance aiming to improve the quality of software products and to increase Brazilian companies' competitive advantages both in the national and international markets. Since 1993, with the foundation of PBQP Software (Subcommittee of Software of the Brazilian Program for Software Quality and Productivity), Brazil invests on Software Quality improvement [2, 3].

Nevertheless, a comparative study of the MIT (Massachusetts Institute of Technology) [4] concluded that Brazilian companies have more interest on ISO 9000 [5] than other models and standards specifically oriented to software. This information is corroborated by the results of a research of the MCT (Ministry of Science and Technology of Brazil). According to this research, the number of software development companies in Brazil in 2003 with ISO 9000 certificate was 214, and the number of companies with SW-CMM (Capability Maturity Model for Software) official evaluations was 30 and none with CMMI (Capability Maturity Model Integration) official evaluation.

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Considering the 30 companies with SW-CMM official evaluations, we can verify that at the base of the pyramid there are 24 companies in the Maturity Level 2, and 5 companies in the Maturity Level 3. At the top of the pyramid, there is a single company in the Maturity Level 4 and none at the Maturity Level 5. Beginning in 2006, organizations must start working on implementing CMMI, since the SW-CMM will no longer be supported by the SEI-CMU (Software Engineering Institute – Carnegie Mellon University).

These data evidence that in order to improve software processes in Brazil, there are two major problems to solve: (i) concerning the top of the pyramid, the question to be solved is: *How to significantly increase the number of Brazilian companies with CMMI official appraisals in Maturity Levels 4 and 5 focusing the companies that export software and other large companies?*; (ii) concerning the base of the pyramid, there is another question that needs to be answered: *How to radically improve software processes in Brazil focusing on a significant number of small and medium size companies so that these companies can achieve CMMI Maturity Levels 2 or 3 within feasible costs?*

This work describes an approach to solve the second problem in the context of the Brazilian Software Process Improvement (mps Br) Project. The approach consists of the development of a Reference Model for software process improvement (MR mps Br) and an appraisal method. The MR mps Br has been deployed in several Brazilian companies located in the state of Rio de Janeiro. Moreover, a Software Development Environment (SDE), named Taba Workstation, were configured and installed in each of these companies aiming to facilitate and accelerate the software processes definition, deployment, and improvement. In order to evaluate the adequacy of the deployed processes and supporting SDE, a survey was planned and implemented.

The next section presents the mps Br Project main objectives and characteristics. Section 3 presents the Reference Model for Software Process Improvement and the appraisal method developed. The pilot experience concerning the deployment of the presented approach in Brazilian software companies, and the main functionalities of the supporting SDE are presented in section 4. Practical results from MR mps Br deployment in small and medium size Brazilian companies, and the empirical evaluation execution results are presented in section 5. Finally, sections 6 and 7 present some lessons learned, and point out future directions and conclusions, respectively.

2 The mps Br Project

Since 2003, 7 Brazilian institutions, with complementary competencies in software process improvement, have participated in the Brazilian Software Process Improvement (mps Br) Project coordinated by SOFTEX (Association for Promoting the Brazilian Software Excellence), a national entity responsible for the SOFTEX program that coordinates the actions of 31 SOFTEX Agents located in 23 cities of the country and with more than 1,300 associated companies. Among these institutions, there are COPPE/UFRJ and RioSoft.

The mps Br Project aims to improve software processes in small and medium size Brazilian companies within feasible costs. It is not an objective of this project to define something completely new concerning standards and maturity models.

In Brazil, some institutions and a reasonable number of SOFTEX Agents have experience in forming and managing groups of companies aiming to improve software processes through the implementation and certification of ISO 9000 standard [6], and to implement and perform SW-CMM evaluations and CMMI appraisals. From this experiences the mps Br Project was conceived aiming to address two situations: (i) to tailor and deploy a Reference Model for software process improvement (MR mps Br) to companies individually; and (ii) to tailor and deploy the MR mps Br cooperatively in small and medium size companies organized in groups to diminish the deployment costs through the division of the overall costs and facilitation of search for financial support sources.

The mps Br Project consists of 6 phases. The objective of the first phase, concluded in March 2004, was to organize the project, to establish its objectives and to define the first version of the Reference Model. The second phase, concluded in June 2004, had the objective to improve the Reference Model, to start the training activities on the model, and to execute the initial experiments deploying the MR mps Br in software development companies. One of these experiments was executed in Rio de Janeiro and is described in this paper. The other phases consist of parallel deployment of the Reference Model in different parts of the country.

3 The Reference Model for Software Process Improvement

The main objective of the mps Br Project is to create and to disseminate the Reference Model for software process improvement (MR mps Br). It is not an objective of the project, as stated before, to define something new concerning standards and maturity models. The novelty of the project is the strategy adopted for its deployment, which considered the characteristics of Brazilian companies. Besides that, the Model has great potential to be replicated in different regions of Brazil and in other countries with similar characteristics, for instance Latin-American countries.

Therefore, the starting point for the definition of the MR mps Br was the analysis of the characteristics of Brazilian companies, the ISO/IEC 12207 and ISO/IEC 15504 standards, and the CMMI model [7, 8, 9].

The reference standard for the software processes of MR mps Br is the ISO/IEC 12207, i.e., this standard is the framework for the definition of the processes that constitute the MR mps Br. Similarly to the ISO/IEC 12207 standard, the MR mps Br defines fundamental processes, supporting processes and an adaptation process. Each company interested in deploying the MR mps Br should select the pertinent processes from that set according to the adaptation process. The expected results for the deployment of the MR mps Br processes are an adaptation of the expected results of the ISO/IEC 12207 processes and activities.

Seven maturity levels were established in the MR mps Br: Level A (Optimization), Level B (Quantitatively Managed), Level C (Defined), Level D (Largely Defined), Level E (Partially Defined), Level F (Managed), and Level G (Partially Managed). Table 1 illustrates how the five maturity levels of the seven CMMI maturity levels are mapped to MR mps Br maturity levels.

Table 1. Mapping of the MR mps Br maturity levels to CMMI maturity levels

MR mps Br Maturity Levels	CMMI Maturity Levels	Processes Names
A (highest)	5	Organizational Innovation and Deployment, Causal Analysis and Resolution
B	4	Organizational Process Performance, Quantitative Project Management
C	3	Decision Analysis and Resolution, Risk Management
D	3	Requirements Development, Technical Solution, Software Integration, Software Installation, Product Release, Verification, Validation
E	3	Training, Process Assessment and Improvement, Process Establishment, Tailoring Process for Project Management
F	2	Measurement, Configuration Management Acquisition, Quality Assurance
G (lowest)	2	Requirements Management, Project Management

For each of these maturity levels, processes were assigned based on the ISO/IEC 12207 standard and on the process areas of levels 2, 3, 4 and 5 of CMMI staged representation. This division has a different graduation of the CMMI staged representation aiming to enable a more gradual and adequate deployment in small and medium size Brazilian companies. The possibility of rating companies maturity considering more levels, not only diminishes the cost and effort of achieving a certain maturity level, but also allows the visibility of the results of the software process improvement within the company and across the country in a shorter time when compared to other models, such as CMMI. The criteria used to divide the processes across the maturity levels G-C were the importance of the process to the company, the facility to implement it and the dependency of the process to the others.

The MR mps Br Appraisal Method for Process Improvement was defined based on the ISO/IEC 15504 standard. The level of deployment of the expected results related to a specific process is evaluated based on indicators that evidence such deployment. These indicators are defined for each company, related to the expected results of a process, and can be one of the following types: (i) Direct, (ii) Indirect, or (iii) Affirmations. Direct indicators are intermediate work products that result from an activity. Indirect indicators are generally documents that indicate that an activity was executed. Affirmations are results of interviews with the project teams of the evaluated projects.

The implementation of an expected result is evaluated according to four levels: (i) TI – Totally Implemented; (ii) LI – Largely Implemented; (iii) PI – Partially Implemented, and (iv) NI – Not Implemented. The appraisal method adheres completely the ISO/IEC 15504 standard appraisal method [8] defined to the staged representation.

A company is considered mps Br level A, B, C, D, E, F or G if and only if all of its units, divisions or sectors had been rated as such level. Since one or more appraisals can be executed in a company, it is possible that parts of a company are rated with different levels. No matter the appraisal context, the evidential document of the appraisal must explicitly state the objective of the appraisal (appraisal scope), and the maturity level ratings.

In order to execute an appraisal, all completed and on going projects started after the deployment of the MR mps Br in the company or the organization unit to be evaluated must be submitted for the appraisal. During the appraisal planning, the appraiser institution must select a sufficient subset of projects that guarantee the representatively of the company or organization unit to be evaluated. Nevertheless, this number should not be less than two completed projects and two on going projects. The result of an appraisal is valid for two years. After this period, the organization must be evaluated either to maintain the same level, or to try to achieve a higher maturity level.

4 Pilot Experience and Supporting Environment

The MR mps Br was deployed by COPPE/UFRJ in 18 small and medium size companies located in Rio de Janeiro forming two groups organized by RioSoft. These companies shared the same training activities, that constituted 44 hours of classes on Software Engineering topics and 20 hours on the MR mps Br and on the organizational processes to be deployed.

Three strategies for deployment of the processes were defined. Some companies opted for starting their improvement process following rigorously the MR mps Br maturity levels, and, consequently, concentrating their initial efforts on the maturity level G process areas. Another set of companies decided to start the work focusing the maturity levels F and G, i.e., these companies decided to address all process areas equivalent to CMMI maturity level 2. One single company decided to start from the maturity level E, because its processes were already defined and institutionalized. These three strategies are perfectly compatible with the MR mps Br and aligned to mps Br Project objectives.

In order to support the deployment of the model, those companies counted on the software process consultants of COPPE/UFRJ, and the CASE tools integrated into a Software Development Environment, named Taba Workstation [10, 11, 12, 13, 14].

4.1 The Taba Workstation: A Software Development Environment to Support Processes Definition, Deployment, and Improvement

Software Development Environments (SDE) have been playing an important role to support software engineers in the execution of software processes through the application of specific procedures that combine integrated tools and techniques in accordance to particular software paradigms. Moreover, SDE are evolving to integrate knowledge management activities within software processes aiming to support developers to produce better software products based on organizational knowledge and previous experiences more effectively [10].

The Taba Workstation is a SDE created to support individual and group activities, project management activities, enhancement of software products quality, and increase of the productivity, providing the means for the software engineers to control the project and measure the activities evolution based on information gathered across the development. The Taba Workstation also provides the infrastructure to the development and integration of tools to support the execution of software processes. Moreover, this infrastructure maintains a useful repository containing software project information gathered across its life cycle.

In order to support the definition, deployment, and improvement of processes defined according to the Reference Model presented in the last section, the Taba Workstation supports the definition of organizational standard processes and tailoring of these processes to specific projects aiming to increase the control and improve the quality of software products. Therefore, the Taba Workstation not only supports software engineers in the execution of software development processes activities, but also provides the means to execute these processes according to organizational software development processes.

The Taba Workstation evolved during the last years to support knowledge management activities integrated to the software processes aiming to preserve organizational knowledge and foster the institutionalization of a learning software organization. Therefore, the main objectives of Taba Workstation are: (i) to support the configuration of process-centered software development environments for different organizations (Configured SDE); (ii) to support the automatic generation (i.e., instantiation) of software development environments for specific projects (Enterprise-Oriented SDE); (iii) to support software development using the instantiated environment; and (iv) to support the management of organizational knowledge related to software processes.

The Taba Workstation tools offer automated support to: (i) adaptation of the organization standard processes for a specific project; (ii) definition of the organizational structure [10]; (iii) acquisition, filtering, packaging and dissemination of organizational knowledge [10]; (iv) planning the organization of specific projects; (v) time, costs, risks [10], human resources planning, monitoring and control [10]; (vi) planning and execution of Configuration Management activities; (vii) identification of software product quality requirements; (viii) documentation planning; (ix) supporting the planning and monitoring of corrective actions; (x) supporting measurement and analysis activities based on the GQM (Goal-Question-Metric) method; (xi) project monitoring through the generation of periodic reports and measures; (xii) controlling of the activities executed during a specific project; (xiii) requirements management; and (xiv) post mortem analysis.

The figure 1, for instance, presents a screenshot of a tool named AdaptPro aiming to support the institutionalization of the standard processes since it facilitates the adoption of these processes in all the projects of the organization. By using the AdaptPro tool, the software engineering can execute the following activities: (i) characterize the project; (ii) plan the process that will guide the project through the adaptation of the organizational standard process considering the project characteristics; and (iii) instantiate a SDE to support the execution of the planned process. On the left side of figure 1, the system presents the activities that guide the execution of the tool.

On the right side of the figure, the system presents another screen to support the execution of the selected activity; in this case, it is presented the screen that supports the definition of a life cycle model to a specific project as part of the process planning activity. A list of life cycle models and the respective level of adequacy to the project considering its characteristics are presented on the right side of the screen. Besides that, the user can consult the justification of the automatic identification of the adequacy level and can consult the software processes defined for similar projects that used the same specialized process and life cycle model facilitating the selection of an adequate project life cycle model by the user. Moreover, the user can consult knowledge related to life cycle models directly from this screen and register knowledge related to the planning process activity, such as lessons learned.

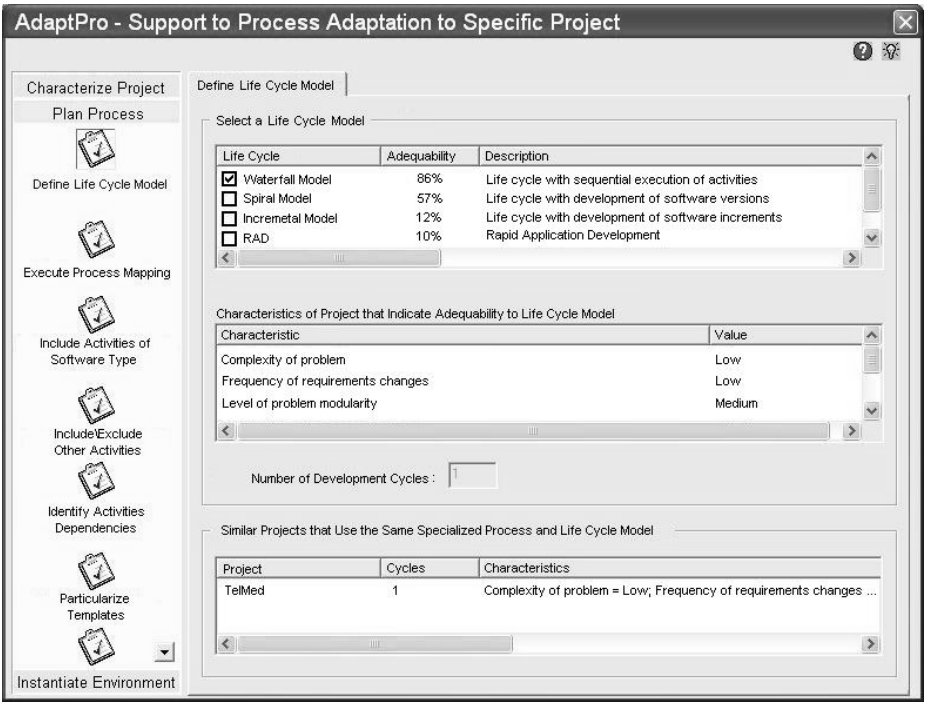

Fig. 1. AdaptPro – a tool to support process adaptation to specific projects

After planning the process, the project manager uses the AdaptPro tool to instantiate the specific process to the project based on its particularities. The product of this tool is the process plan (including adaptations to support the life cycle model chosen) and a SDE to support the execution of the planned process.

The AdaptPro tool, just like the other tools of the Taba Workstation, is integrated into the Taba Workstation Knowledge Management tools. The practical results obtained from the MR mps Br deployment with the support of the Taba Workstation tools are presented in the next section.

5 Practical Results from MR mps Br Deployment in Small and Medium Size Brazilian Companies

The processes deployment in small and medium size companies demonstrated several benefits, such an increase of product and process quality, and preservation of organizational knowledge related to software processes. A direct benefit obtained from the processes deployment can be exemplified by three companies that obtained ISO 9000:2000 certification based on the software process deployed.

The first company to obtain the ISO certification is a software development company that during the previous two years was involved in software processes definition, preparation and deployment without success. One year after the beginning of the mps Br Project, the company obtained the ISO 9000:2000 certification [15].

The second company to obtain the ISO certification is a software development company that already had the ISO 9000:1994 certification and had to be compliant with the ISO 9000:2000 standards in order to renew their certificate. According to the software engineers of the company, the deployed processes and the Taba Workstation support were decisive to obtain the certification renewal, because it has speeded the deployment of software processes, and had facilitated the dissemination of organizational best practices.

The third company to obtain the ISO certification achieved this goal on February of this year. Moreover, a successful SCAMPI official appraisal was conducted on March of this year aiming to evaluate the same company on the CMMI Level 2 process areas [16]. These two evaluations were conducted after only 8 months since the beginning of the processes deployment initial activities.

These results not only demonstrate the feasibility of the deployment of MR mps Br, but also reinforce its compatibility to CMMI process areas and ISO standards. Moreover, the quality of the software processes enhanced because the companies implemented their processes based on standards and maturity models.

Official MR mps Br appraisals are going to be executed aiming to evaluate five companies until the end of this year.

5.1 Empirical Evaluation Results

A survey was planned and executed with the objective to analyze the processes deployed and the Taba Workstation supporting tools, with the purpose of evaluation with respect of the adequacy under the point of view of project managers, system analysts and developers in the context of software engineers executing the deployed processes with the support of the Taba Workstation tools.

The survey was executed through the application of questionnaires to 16 key members of the companies that took part of the initial phase of the mps Br Project. These members had to fill out a form containing sets of questions addressing different concerns. The questions were divided into four sections. The first section contained specific questions concerning the experience of the participant. The second section contained questions related to the deployed process. The third section addressed questions about the Taba Workstation supporting tools. Finally, section four contained

questions related to the activities and procedures specific of the process areas. Figure 2 presents the results of the execution of this empirical evaluation.

From the results presented in figure 2, we can notice that the activities and procedures specific to the process areas were always adequate for most of the participants. Moreover, more than 90% of the participants recognized that the Taba Workstation significantly reduced the effort for executing most of the process activities. Although nearly 85% of the participants stated that there was adequate sensitization in the companies concerning the importance of the use of the processes, almost 65% of the participants noticed resistance to the deployment of such processes. In order to cope with this divergence, the high-level management demonstrated strong support for the processes deployment and stimulated the participants to develop the projects according to the defined process. As a result, we can observe in figure 2 that most of the projects were always developed according to the defined processes, and the team members recognized that such processes were actually adequate to the projects.

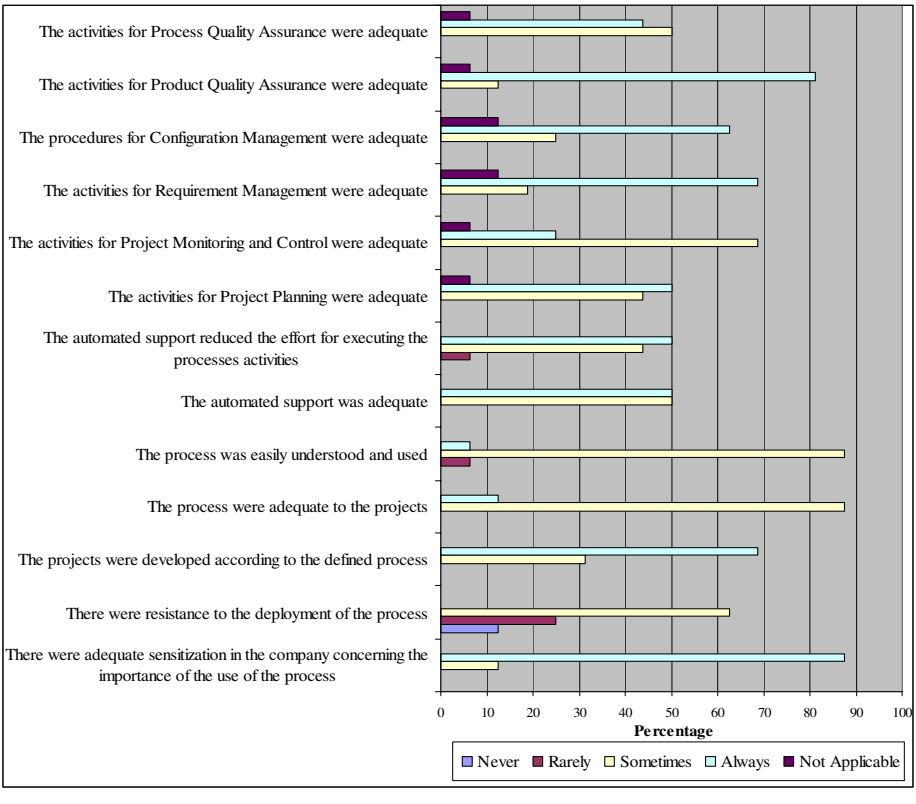

Fig. 2. Empirical evaluation results of the processes and the Taba Workstation support

The participants of the experiment also identified that both the processes and the Taba Workstation facilitated the dissemination of best practices from the project planning until the post–mortem analyses. Moreover, the centralization of information

and knowledge related to processes execution also supported decision-making situations, because project managers could easily consult information about similar projects. The institutionalization of the processes with Taba Workstation also facilitated the communication among the project team members and diminished the occurrences of misunderstandings along the project concerning the procedures and activities to be executed and the artifacts to be produced.

6 Lessons Learned

Some lessons were learned from the results of the experience of the MR mps Br deployment: (i) a generic and comprehensive model is very important to allow a great variety of deployment processes that depends on particularities and size of the companies involved; (ii) the cooperative deployment in a group of companies has been demonstrating adequate and capable of satisfying the reality of small and medium size companies, because it allows the deployment of the model within a more feasible cost and maintaining the good quality; (iii) the experience and consultants background level, and the existence of a companies group coordination that drives the groups actions in an adequate way are fundamental aspects for success of the deployment of the MR mps Br; (iv) the work with a group of companies demands a high number of consultants in order to give the necessary attention at the moment the companies need it the most; (v) the participation in a group demonstrated not to be adequate for companies with a high level of specificity or that already has a defined and institutionalized process; in such cases, individual deployment is more suitable; (vi) the training activities for developers, system analysts and project managers have been positively evaluated and we intend to increase their comprehensiveness in the next trainings; and (vii) the Taba Workstation supporting tools demonstrated to be adequate to facilitate the processes use and deployment, reducing time and effort for the institutionalization of such processes within the companies.

7 Conclusion

This paper presented the mps Br Project. The project has been achieving a high level of adherence by private companies and governmental organizations. The search for a solution that really satisfies the characteristics of Brazilian companies has been involving a great discussion and an effort of a large team represented by professionals from different regions of Brazil.

The mps Br Project has seven differentials that characterize it: (i) seven maturity levels that allow a gradual deployment, and is adequate to small and medium size companies, and that allow the increase of visibility of both the processes and the improvements; (ii) compatibility to ISO/IEC 12207, ISO/IEC 15504 (SPICE) and CMMI; (iii) developed to the reality of Brazilian companies; (iv) software process deployment cost feasibility; (v) periodic appraisals (from 2 and 2 years); (vi) great potential to be replicated in Brazil and other countries; and, (vii) defined and deployed with a great industry-university cooperation constituting a catalyser of business and technology developments.

This paper also presented a pilot experience concerning the deployment of the presented approach in Brazilian software companies, and the main functionalities of the Taba Workstation SDE. Practical results from MR mps Br deployment in small and medium size Brazilian companies, and the empirical evaluation results were presented and analyzed aiming to identify the benefits of the presented approach and future directions for the project.

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