CERTICS - A Harmonization with CMMI-DEV Practices for Implementation of Continuous Improvement Competence Area

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Abstract

This paper proposes a harmonization between a product quality model and a software process model used in the industry, CERTICS (a national Brazilian model) and CMMI-DEV (an international model). The focus of this harmonization is on the Competence Area of Continuous Improvement of CERTICS, which addresses the key question of whether the software is the result of Continuous Improvement actions originating in the management of personnel, processes and knowledge to support and enhance their development and technological innovation. The results of the harmonization are examined step by step, as well as including a review of the harmonization, and were assisted by an expert on the CERTICS and CMMI-DEV models. Thus, this paper aims to correlate the structures of the two models to reduce the implementation time and costs, and to stimulate the execution of multi-model implementations in software development.

keywords: software engineering; software quality; continuous improvement; CERTICS; CMMI-DEV; harmonization.

1 Introduction

The growing use of software in companies means that most manual work is now automated, as well as most business routines [1]. This can be regarded as a benefit since the adoption of software products generates a greater demand for goods and services. The increase in demand leads to a proportional increase in customer requirements. Thus, the requirement for greater quality in software products is increasing, since these customers are becoming more selective with regard to the software products they find acceptable [2].

There are several certified models on the market to ensure the quality of the software products, such as the Capability Maturity Model Integration (CMMI) [3], the International Organization of Standardization / International Electrotechnical Commission (ISO / IEC) 15504 [4] and Six Sigma [5]. In Brazil, there are two models that are gaining prominence, which are Brazilian Software Process Improvement (MPS.BR) [6], and the Certification of National Technology Software and Related Services (CERTICS) [7]. From an analysis of the statements of conformity of CERTICS Model with the ISO/IEC 15504-2 requirements for Process Reference Model and Process Assessment Model available in [11], the authors conclude that CERTICS Model can be considered as a Process Reference Model and Process Assessment Model. From similar analysis for ISO/IEC 15504-7 requirements they also conclude that CERTICS Model can be considered as an Organizational Maturity Model.

Brazil is a country, which has one of the world’s largest range of software products, and every day the requirements of customers regarding the quality and complexity of products is increasing. From this standpoint, it can be observed that companies are increasingly seeking maturity in their software processes so that they can reach international standards of quality and productivity, which are essential for survival in the IT market. However, the cost of certification for a company can be up to US$ 400,000, which is not feasible for micro, small and medium-sized firms, and is a characteristic of Brazilian IT Enterprises. Because of this, the Department of Information Technology of the Ministry of Science, Technology and Innovation launched a number of Government and marketing initiatives, which led to a more aggressive stance to export-oriented software. These involved the creation of models to comply with the features required by national companies, and the recent investment policies for the training and expertise of professionals [6][7].

Despite the wide range of certification models, many companies seek to make improvements in their processes and products by using more than one of these models. The reason for this is that the practices included in a single one cannot fully comply with their requirements for improvement. The great difficulty in the implementation of more than one model is that each has a different kind of structure, which causes conflicts and problems about how to understand the models, which will be implemented in the company. These implementation problems that are found in more than one model can only be reduced by achieving a harmonization between them. This task will help to identify the similarities and differences between the models [8].
harmonization is fully accepted by the regulatory bodies as a means of obtaining quality in the products and services related to software.

The research question of this paper is about how CERTICS (product quality model) and CMMI-DEV (process quality model) can help to bring about an organizational improvement in an integrated way by using the assets (practices, processes and others) that these models possess. Thus, this research is driven by the need for materials that guide the implementation process of the multi-models (CERTICS and CMMI-DEV) in companies, by providing assets to identify their strengths and weaknesses. Furthermore, this research aims to show the relationship between the CERTICS and CMMI-DEV quality models, by harmonizing their features to show the level of adhesion between their structures and support organizations that want to implement them together. The description of the main objective concerns the application of the practices defined in the quality models for the software process and product.

The extent of the business / scientific problem and its challenges is revealed by the number of existing models that focus on improving the quality of software development. The harmonization can help to identify the common features of these models, by providing the software company with an instrument to guide the joint implementation of its practices, and thus reduce time and costs. Thus, the means of tackling this problem is to determine how many assets (practices, processes and others), which are needed to support the implementation of different models, can be applied together in the software company.

In this paper, there are discussions related to the details of the harmonization of the CERTICS model of Continuous Improvement competence area with the CMMI-DEV model. In describing the similarities between the structures of the models, the coverage criteria and evaluation are performed to validate the correctness of the harmonization between the models. Thus, the purpose of this paper is to design an instrument that can guide the joint implementation of the practices contained in the two models (CMMI and CERTICS).

Several questions need to be addressed in this research: these include the way the nature and scope of the investigated problem are related to the software quality and the improvement of the process and product. They also involve an attempt to ensure that, within the scope of the process improvement in practice, the improvement of the software products can be achieved.

According to CTI Renato Archer [7], the model of CERTICS provides benefits to Brazilian software development companies that seek to gain preference in government procurement and market differentiation, and thus create a positive image of the company as an innovator of software development and technological progress in the country. Until October 2016 this model had 32 products certified and registered on the site [7].

CERTICS is composed of four competence areas. The choice of the Continuous Improvement area for this work was based on the fact that it seeks to ensure that the software product is the result of continuous improvement actions through improvement activities covering organizational areas such as management of personnel, knowledge and processes. It includes several actions aimed for better management of human and material resources, and focus on the knowledge dissemination acquired about the technologies present in the software, so that this knowledge is shared in the organizational unit. This allows the organizational unit is in constant evolution, always seeking to improve and innovate in their products, so it is of great importance to encourage its employees so that they can help identify and propose new improvements that can be implemented in the organization in order to enhance the technological development and innovation within the organizational unit [7].

Thus, it is expected that the results of this research will: a) reduce the burden of companies with joint implementation models, b) reduce inconsistencies and conflicts between models, and c) reduce costs through this kind of implementation. The difficulty is how to harmonize two models that are defined by different organizations and decide which practices should be integrated. Finally, this research is constrained by being concentrated in one CERTICS competence area and, for this reason, an expert has been invited to evaluate the harmonization.

This paper is structured as follows. Section II discusses the two models of this research in detail. Section III outlines the harmonization of the Continuous Improvement competence area of CERTICS with regard to CMMI-DEV practices. Finally, Section IV concludes with some final considerations. These include the results obtained and the limitations of this research, followed by some suggestions for possible future work.

2 Related Works and Background

This section provides an overview of the concepts of the CMMI-DEV and CERTICS models.

2.1 The CERTICS Model

CERTICS is a Brazilian evaluation methodology that seeks to determine whether or not software is the result of technological development and innovation in the national sphere. In this way, it seeks to assess whether the product developed "creates or expands technological skills that are related to the country, or contributes to the creation of business based on knowledge. This leads to an increase in technological autonomy and innovative capacity." [7].

The CERTICS methodology was designed on the basis
of the ISO / IEC 15504-2 standard [4] and aims to define a minimum set of requirements related to technological development and innovation in the country [7].

The CERTICS model is composed of four Competence Areas and sixteen Outcomes. The Competence Areas include the details about the concepts of the resulting software that is used for technological innovation and the development of the country. Each Competence Area has a key feature that describes characteristics that must be reached in order to fulfill the requirements of the model. The competence areas are as follows:

- **Technological Development (DES)**, key question - “Is the software the result of technological development in Brazil?”,
- **Technology Management (TEC)**, key question - “Does the software remain technologically autonomous and competitive?”,
- **Business Management (GNE)**, key question - “Does the software leverage knowledge-based business and is it driven by these business?”,
- **Continuous Improvement (MEC)**, key question - “Is the software the result of Continuous Improvement originating in the management of personnel, processes and knowledge to support and enhance their development and technological innovation?”.

The Competence Areas have a set of outcomes, which, when implemented, must satisfy the goals of the model. The model also provides guidance about how to implement each outcome, as well as a list of examples of work products that illustrate what is desirable to fulfill each outcome [7]. In the domain of this work area, the Outcomes of the Continuous Improvement Competence Area are:

- **MEC.1. Contracting, Training and Incentive to Qualified Professionals**, qualified professionals are contracted, trained and encouraged to carry out activities related to software,
- **MEC.2. Knowledge Dissemination related to Software**, the knowledge related to software, generated in technological and business activities is disseminated, and
- **MEC.3. Improvement Actions in Processes**, improvements in processes of technological and business activities related to software are made.

### 2.2 The CMMI-DEV Model

CMMI is a maturity model for process improvement that is created by Software Engineering Institute (SEI) to integrate knowledge areas in a single model, such as Systems Engineering (SE), Software Engineering (SW), Integrated Products and Process Development (IPPD) and Supplier Sourcing (SS) [3].

Currently the CMMI is in version 1.3 and is composed of three models, which are: CMMI for Development (CMMI-DEV), which is concerned with development processes, CMMI for Acquisition (CMMI-ACQ), whose focus is on acquisition processes, as well as product and / or services sourcing, and CMMI for Services (CMMI-SVC), which deals with service processes such as maintenance and evolution.

The CMMI structure consists of several elements that are grouped into three categories, which are: a) required components (Specific and Generic Goals), b) expected components (Specific and Generic Practices) and c) informative components (Subpractices, Examples of Work Products, and others). These components assist in the interpretation of the model requirements. Thus, the CMMI-DEV is composed of twenty-two process areas, which consist of its purpose and specific goals for each area supplemented by generic goals, since they are related to all the process areas. The specific goals define unique characteristics for each process area, while the generic goals define characteristics that are common to all the process areas. Each specific goal has a set of specific practices, which are activities that must be taken into account to ensure that the goal is satisfied. Similarly, the generic goals have generic practices.

### 3 The Harmonization between CERTICS and CMMI-DEV Models

The CERTICS and CMMI-DEV models have different structures, each of which has a set of specific requirements, however, despite the particular features of each model, it can be inferred that the models have elements that can influence the fulfillment of some of the requirements that can be found in both models, according to Table 1.

<table>
<thead>
<tr>
<th>CERTICS Elements</th>
<th>CMMI-DEV Elements</th>
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</thead>
<tbody>
<tr>
<td>Competence Area</td>
<td>Process Area</td>
</tr>
<tr>
<td>Key Questions</td>
<td>Specific Goals SG</td>
</tr>
<tr>
<td></td>
<td>Generic Goals GG</td>
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<tr>
<td>Outcomes</td>
<td>Specific Practices SP</td>
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<td></td>
<td>Generic Practices GP</td>
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<tr>
<td>Guidelines</td>
<td>Subpractices</td>
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<tr>
<td></td>
<td>Generic Practice Elaborations</td>
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<tr>
<td>Evidences from Processes related with Software</td>
<td>Example of Work Products WP</td>
</tr>
</tbody>
</table>

The CERTICS model is formed of Competence Areas, which have a set of practices (outcomes) that must be implemented so that it can fulfill the requirements of the model. Similarly, the CMMI-DEV model has an element called Process Area, which is also composed of many practices that must be implemented to fulfill their goals; these practices are called Specific and Generic Practices.

The Key Questions of the CERTICS model are similar in some respects to the Specific Goals and Generic Goals of
CMMI-DEV, because these three elements have a set of characteristics that must be identified in a company to ensure that it fulfills the requirements of the model. Thus, the Outcomes of the CERTICS model have goals that can be equated with the Specific Practices and Generic Practices of CMMI-DEV, since these features represent the details of the requirements with regard to what should be performed as a practice to ensure the goals of these models are achieved.

It should be noted that when guiding the implementation process of these models, both have some elements that help to bring about a correct implementation of the requirements of the models. In the CERTICS model there are Guidelines and in CMMI-DEV there are Subpractices and Generic Practice Elaborations, which offer guidance about how to implement each kind of model item.

Similarly, it was found that the Evidence of the CERTICS model also had goals that can be equated with the Example Work Products of CMMI-DEV, because these elements can act during the implementation of the models as a reference-point for what can be used so that it can provide evidence that the requirements of each model have been fulfilled.

The set of supporting concepts adopted in this paper defines a set of technologies that can be integrated to assist in the software process appraisal and improvement. In this domain, there are tools, techniques, procedures, processes, roles, methodologies, frameworks, languages, standards, patterns, and so on.

3.1 The Conformance Analysis of the Competence Area of Continuous Improvement

The competence area of Continuous Improvement has four outcomes, which are designed to ensure that the software is the result of continuous improvement actions originated in the people, processes and knowledge management aimed at supporting and enhancing their development and technological innovation [7].

A. MEC.1: Contracting, Training and Incentive to Qualified Professionals

The MEC.1 outcome seeks to analyze if qualified professionals are contracted, trained and encouraged to carry out activities related to the software. Thus, this outcome needs a set of CMMI-DEV Process Areas and Practices to achieve its goals.

In the Project Planning (PP), the Specific Practices SP.2.5 and SP.2.6 allow to properly plan the skills and the involvement of stakeholders, so that only qualified professionals are involved in the project.

In the Project Monitoring and Control (PMC), the SP.1.1 and SP.1.5 allow to monitor the actual values of project planning parameters against the project plan, and monitor the data management based on the project plan together with Project Planning SP.2.5 and SP.2.6 seek to ensure that professionals carry out their activities with competence.

In the Organizational Training (OT), the SP.1.1 seeks to maintain training based on organizational strategies and needs, in SP.1.2 determines which training needs are the organization and what are the projects, which can help to prove the organizational unit identifies the needs for the training of its employees are conducted. In this sense, the SP.1.3 seeks to establish and maintain tactical plans of training, as well as the quality of this training in order to meet the identified needs which is made possible with the implementation of SP.1.4. In SP.2.1 seeks to provide the training according to the tactical plan of training, while the SP.2.2 establishes and maintains records of training in the organization, finally the SP.2.3 is focused on evaluation of training about effectiveness in the organization.

In the Generic Practice (GP), the GP.2.5 ensures that those involved in the project are qualified in terms of education, training and experience.

The coverage of this expected result by the CMMI-DEV was partial, because the CMMI-DEV makes no requirement related to: (i) implementation of incentive programs to the organization’s staff, (ii) the requirement of proof of actions for contracting and training of professionals for activities related to technological and business development, (iii) actions focused to the activities related to software support and evolution.

B. MEC.2: Knowledge Dissemination related to Software

The MEC.2 outcome has the focus on the knowledge dissemination related to software, generated in technological and business activities.

For this reason, when the CMMI-DEV model was analyzed it was found that this model does not cover this outcome because the model makes no requirement related to knowledge dissemination that is generated in the software product development and the business activities present in the software.

C. MEC.3: Improvement Actions in Processes

In this outcome the improvements in the processes of technological and business activities related to software must be made. In this sense, the CMMI-DEV has some practices that may be related to the fulfillment of this goal.

In the Generic Practice (GP), the GP 2.2 aims to ensure that it is established and maintained the plan for performing the process.

In the Organizational Process Definition (OPD), the SP.1.1 aims to establish and maintain the description of the organization’s process goals and needs.

In the Organizational Process Focus (OPF), the SP.1.3 aims to identify improvements to process and organizational
process assets. In the SP.2.1 the organization shall establish and maintain the plans for improvements and in the SP.2.2 the implementations of these improvement must be performed when necessary. Also in OPF, the SP.3.1 focus of the implementation of process assets in the organization, and the SP.3.2 aims to implement the standard processes in the organization’s projects.

In the Organizational Performance Management (OPM), the SP.1.1 practice seeks to maintain the business goals based on the understanding of the organization’s business strategies and their current performance results.

The CMMI-DEV practices that were related to this outcome allowed to evidence that improvement actions in the processes are made, attending completely to this outcome.

### 3.2 The Evaluation of the Harmonization of Continuous Improvement

The peer review technique was employed to evaluate the harmonization between the requirements of the CERTICS and CMMI-DEV models outlined in the last section. This was overseen by an expert, who has over five years of experience with the implementation of quality models in software development companies, and has recognized certification in CERTICS and CMMI-DEV models. The expert received the document that contains the harmonization of CERTICS and CMMI-DEV models, and carried out the review in accordance with a set of criteria, which were defined on the basis of Araújos’s work [8], as shown in Table 2.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Definition</th>
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<tbody>
<tr>
<td>TH (Technical High)</td>
<td>Indicates that a problem in a harmonization item was found and, if not changed, would impair the system.</td>
</tr>
<tr>
<td>TL (Technical Low)</td>
<td>Indicating that a problem in a harmonization item was found and a change would be appropriate.</td>
</tr>
<tr>
<td>E (Editorial)</td>
<td>Indicating that a Portuguese language error was found or the text can be improved.</td>
</tr>
<tr>
<td>Q (Questioning)</td>
<td>Indicating that there were doubts about the content.</td>
</tr>
<tr>
<td>G (General)</td>
<td>Indicates that in general a commentary is needed.</td>
</tr>
</tbody>
</table>

Table 2: Criteria defined for the Harmonization Evaluation

When reviewing the harmonization of Continuous Improvement (MEC) Competence Area, the expert detected a problem, which was classified as General (G). It was suggested that an analysis should be conducted of all the CMMI-DEV specific and generic practices that have been mapped in the MEC area with the aim of determining whether they are listed and described at the end of the document. If any mapped practice had not been listed, the expert suggested that it should be included in the document, as a means of enabling the goal of these practices to be understood.

The expert has identified two errors in MEC.1, which were classified as TH and TL. The first classification (Technical High) was referring to the incorrect relationship of one SP in PMC, where it was necessary to replace the PMC.SP.1.4 of CMMI-DEV to PMC.SP.1.5. But the error classified as TL was referring to the absence of the name of a Generic Practice in the mapping document, and to include it in this document.

In MEC.3 outcome the expert found that the name of a Generic Practice was absent, then he recorded that there was a problem classified as TL in this outcome, the suggestion to correct this problem was to add the Generic Practice in the document.

It is important to emphasize that this work did not consider any quantitative metrics to evaluate the harmonization between the two models, since this evaluation happened in a qualitative way using the peer review method. However, the amount of items answered by each criterion by the reviewer generated a quantitative metric to represent the quality level of the result generated by the harmonization.

### 3.3 How should the Harmonization be used?

The purpose of the harmonization of CERTICS and CMMI-DEV models is to help businesses that wishing to obtain certifications through multi-model implementations or even by making evaluations of the two models. The use of harmonization can optimize costs, time and effort because the models now have their structures harmonized and interrelated.

It was possible to find and highlight the differences and similarities included in the requirements of CERTICS and CMMI-DEV models. In this way, it can be seen that although some requirements of the models are similar or even complementary, it is not always possible for them to fulfill their goals in the same way. According to Association for Promoting Excellence in Brazilian Software (SOFTEX) [6], this may occur because of the different level of requirements found in some of the practices, outcomes and expected results of the models.

The harmonization spreadsheets have become an important support tool in the joint evaluation or implementation of the models, because they provide inputs that allow adaptation / harmonization in the frameworks of the models and in their expected results, practices and outcomes. This can enable the multi-models to be implemented in companies.

As a result, the company saves time from the implementation of joint models, because it will not have to spend time on separately analyzing the frameworks of the models. This means that it has to determine in what way a model can suit another one. This is because all the structures and requirements, which are the same for all the models, have been identified, harmonized and documented in the harmonization spreadsheet of the models.
4 Conclusion and Future Work

This research study has examined the harmonization of Continuous Improvement Competence Area included in CERTICS with CMMI-DEV practices. To achieve its goals, this research sought to identify the similarities and differences between the CERTICS and CMMI-DEV frameworks by investigating their harmonization. To avoid problems of understanding and inconsistencies, an expert in the models evaluated the harmonization by the peer review technique. The results of this review were analyzed and suggested changes should be implemented to eliminate inconsistencies and problems of understanding problems, which were detected by the expert. The document with the complete harmonization generated after the peer review, including all the CERTICS Competence Areas is available in [9].

The usability of the harmonization of the two models can be corroborated by numerous certifications registered in the CERTICS website [7] about products developed by Brazilian software companies that have also made appraisals of their processes that are outlined in the CMMI website [3]. This shows that there is national interest in the two models.

The lessons learned from this research stem from the fact that there is an analytical and comparison domain between the models. Thus, it is recommended that more than one person perform it, so that any conflicts or uncertainties can be discussed and solved by a peer review.

One drawback of this study is that the harmonization has not been evaluated in a software development company; it has only been evaluated by peer review. An evaluation of the harmonization in a company is being completed in Brazil, and its processes are in accordance with the practices of CMMI-DEV Maturity Level 3. As a result, it is possible to determine whether the harmonization contributed positively or negative to a multi-model implementation. Another drawback is the fact that the peer review has only been performed by a single expert, which means that it can only be a limited view of the results obtained from the research. However, this expert is a part of a team that specifies the CERTICS model, and he has extensive experience with the implementation of the CMMI-DEV model, and reduces the bias of the results obtained from the review.

In the future, we intend to continue expanding this research, and apply it to other enterprises, and thus allow the positive and negative aspects of the use of harmonization in a CERTICS multi-model implementation with the CMMI-DEV to be quantified. Another future study concerns the definition of the complete cycle of a harmonization based on the research results of Araújo’s work [8] and the SOFTEX guide [10].

So far now that the case study has not been completed, it is possible to perceive that the benefits of joint implementation are as follows: a reduction in costs and time to fulfill the expected results and practices in CERTICS and CMMI-DEV models, creation of unified and standardized evidences to achieve the two models, and the standardization of technical language, which is employed in these models, to define the software development process.

References