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An Approach for the Implementation of Software Quality Models Adopting CERTICS and CMMI-DEV

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***Abstract*— This paper proposes a mapping between two product quality and software processes models used in the industry, the CERTICS national model and the CMMI-DEV international model. The stages of mapping are presented step by step, as well as the mapping review, which had the cooperation of one specialist in CERTICS and CMMI-DEV models. It aims to correlate the structures of the two models in order to facilitate and reduce the implementation time and costs, and to stimulate the execution of multi-model implementations in software developers companies.**

***Index Terms*— CERTICS, CMMI-DEV, Model Mapping, Multi-Models Quality Models, Software Quality.**

I. Introduction

Given the fact that the organizations have been using software, a large part of the manual work started to be automatized, as well as most of the routines in the organizations [1].

The benefits achieved by the adoption of software products end up creating a large demand, given that the organizations become more dependent on the benefits the software products offer.

Just as the software demand rises, the clients also demand a higher level of quality. This way, the software need to achieve an even higher quality level, given that the clients are becoming more deliberate in the acceptance of software products [2].

In order to ensure the quality of the software products, there are several certification models in the market, such as the CMMI – *Capability Maturity Model Integration* [3], ISO/IEC 15504 [4] and Six-Sigma [5]. In Brazil, there are two models that have become more known, the MPS.BR – Improvement of the Brazilian Software [6], e and the CERTICS model – Certification of National Technology of Software and Related Services [7].

Brazil is a country whose software product development ranks between the higher in the world and each day the clients demand higher quality and complexity levels from the products. Because of this, we can see that the companies are search more maturity on their software processes in order to achieve international standards of quality and productivity, which are essential to survive in the IT market. Nevertheless, the certification cost can amount to US$400.000, which makes it not viable to small and medium sized companies, which comprise most of the IT national companies. Because of that, the Computer Science Policy Secretariat from the Science, Technology and Innovation Ministry began several initiatives both from the government and from the market sides to signal the transition to a more aggressive posture towards software export: the creation of models to answer to these characteristics of national companies and recently, the creation of investment policies in qualification and specialization of the IT professionals [6, 7].

In spite of the great diversity in certification models, organizations tend to adopt more than one of those, because a single one does not always contemplate all their needs, given that the models have complementary demands. The major difficulty in the implantation of more than a model is that each one has a different type of structure, what ends up generating conflicts and problems of understanding between the models that will be implemented in the organization.

In order to diminish those problems in the implantation of more than a model, it is necessary to perform a harmonization of the models, a task that allows us to identify the equivalent parts in the models' structure and the difference between them [8], This harmonization is fully accepted by the normative organisms as a complementary way to get software related products and services quality.

Hence, this work is justified by the need for materials that can direct the implantation of multiple models in the

organizations, offering subsidies for the identification of strong and weak points in each model. Besides, this research intends to show the relationship between the quality models CERTICS and CMMI-DEV, by performing a mapping between the two models.

We chose CERTICS because according to [7] this models allows benefits for software developing companies because its adoption may increase business opportunities dues to preference in purchase processes [14] and because it builds a positive image of the organization as a software developer that brings technological innovation to the country. Until September/2015, this model presented a grand total of 27 products certified and listed at its site (*www.certics.cti.gov.br*).

Given this information, we expect that the results of this research may reduce the effort organizations have to spend with joint model implantation, minimizing inconsistencies and conflicts between models, besides cutting costs for this type of implantation.

This paper is organized as follows. Section II presents works that are similar to this research, which perform the harmonization of two or more models. Section III describes the research methodology, detailing each step of the development of this work. Next, Section IV presents the mapping of the models CERTICS x CMMI-DEV. Section V contains the results of the peer review that was performed on the mapping as an evaluation process. Finally, Section VI contains final considerations, limitations of this research and some possible future works.

II. Related Works

The work by Baldassare et at. [9] proposes a harmonization model that intends to support and guide the organizations interested in the integration, management and alignment of software development and quality management practices, or that intend to improve those that already exist. This is possible through the mapping of the norm ISO 9001 and the CMMI-DEV model using the GQM (*Goal Question Metrics*) for the definition of operational goals. In this work the declarations of the norm ISO 9001 can be reuse in CMMI evaluations.

Basically, the harmonization process proposed by Baldassarre *et al*. [9] is made of two sub-processes: theoretical comparison and application process.

In the theoretical comparison process, the organizational artifacts are used as input and initially identified. The process output is a comparison document that points out the relationship between the ISO-9001 norm and the CMMI-DEV, considering that the organization has both certifications. From that point on it was possible to identify whether the ISO norm satisfies the requirements of CMMI and the existence of superposition areas, which allows for reuse of data and information from ISO for evaluation of any of the CMMI levels.

The application process uses the results found with the execution of the management system of a specific organization. In this process the GQM method is used to formalize a quality model according to the superposition areas, reusing data and information found in the first sub-process.

Pardo [10] performs a systematic review of the literature of the existing proposals of reference models for the harmonization of process improvement. In this paper it was possible to identify a considerable increase in the publication of papers with emphasis on multi-models, where 38% harmonize the ISO norm with the CMMI model. The fact that so many of these papers exist is due to the subjectivity of the understanding of the practices and demands in those models by the professionals in this field. Integration and implementation of evaluation models in different reference models for process have been studies, and 25% of those studies propose a solution to support multi-model harmonization.

Pelszius and Ragaisis [11] present a mapping and correspondent approach between the maturity levels of the CMMI-DEV model and the ISO/IEC 15504 norm (norm that defines a reference model for the process that identifies and describes the set of processes considered universal and fundamental for the good practice of software engineering and defines six levels of capacity, sequential and cumulative, that can be used as a metric to evaluate how an organization is performing a specific process, but can also be used as an improvement guide). The authors investigated which maturity levels of a model were guaranteed by each level of the others. Hence, the mapping was divided into the following steps:

(i) Elements of the CMMI-DEC Process Areas were mapped to the process indicators of ISO/IEC 15504;

(ii) Summarization of each level mapped in the models, that is, the CMMI practices that were mapped to the outputs of ISO/IEC 15504;

(iii) Calculation of the percentage of the process attributes of ISO/IEC 15504, that is, determination of the capacity degree to which a company executes its process in alignment with the demands of this norm;

(iv) Definition of the indicators to Express the capacity of each process as N to non performed, P to partially performed, L for legally performed and F, for fully performed;

(v) Establishment of the capacity of the ISO/IEC 15504 processes; and

(vi) Determination of the organizational maturity according to ISO/IEC 15504, guaranteeing the maturity level according to CMMI-DEV.

Hence, the authors observed that the CMMI-DEV maturity levels are totally compatible with the ISO/IEC 15504 capacity levels.

Furtado and Oliveira [12] presented a framework for the process of software and services acquisition that refers to the recommendations and good practices to improve the processes of existing models, such as CMMI-ACQ and MPS.BR Acquisition Guide. Besides, the study offers the development of a free software tool to support the implementation and execution of the framework under study. A theoretical review over both models was performed in order to render the mapping viable. This mapping took into consideration the following items from each model:

(i) tasks predicted in the MPS.BR Acquisition Guide; and

(ii) specific practices of CMMI-ACQ.

The proposed framework was evaluated by experts and the results gathered were analyzed and prioritized with the indication of weak points and the opportunities for improvement. Besides, nowadays the framework is used in at least ten organizations with focus in the Acquisition of Software and Related Services. In order to support the systematization of the activities defined in the framework, a tool called Spider-ACQ was developed. This tool contemplates all activities defined through 65 use cases and is integrated with project management and deviation analysis tools. The framework was divided into four phases to organize the execution of the activities, which are:

(i) Preparation of the acquisition;

(ii) Supplier selection;

(iii) Acquisition monitoring; and

(iv) Client acceptance.

In order to make organizations aware of the knowledge of the capacity and maturity of the process a methodology can guarantee, the work of Peldzius and Ragaisis [11] propose a framework for model harmonization called TSPM (Transitional Software Process Model that allows the transformation of results according to the evaluation of a process model for other models, determine the capacity/maturity that a methodology can guarantee, besides guaranteeing the transition of results of the existing evaluation for a new version of the model without a new evaluation. TSMP has the same maturity levels as ISO/IEC 15504 and CMMI and the defined structure is the following: organizational process name, process name, process goal, process output, practice, generic property and generic practice. Hence, it is a generic framework that can be applied to any pair of models.

Garcia-Mireles et al. [13] present results from the harmonization of product quality processes and models. This work uses a differentiated approach in relation to the previous works, being guide by the software product quality improvement goals. For the mapping between process models, the following four steps were defined:

(i) Model analysis;

(ii) Mapping definition;

(iii) Mapping execution; and

(iv) Mapping result evaluation.

Garzás et al. [14] approach the use of adaptation in some models of the ISO norm in the creation of a organizational maturity model for the software industry with the goal of supporting the improvement of software processes in several organizations and, consequently, help them achieve better conditions to get a maturity certification. The framework called AENOR was developed with the goal of improving the software process of small Spanish companies. The proposed models specifies the following three components:

(i) capacity and maturity evaluation model;

(ii) software process life cycle model; and

(iii) auditing process, based in some ISSO norms.

AENOR has a structure similar do CMMI, being composed of processes and attributes, genetic practices and work process. Besides, the mapping is made according to the processes of each model.

Finally, Araújo [8] presents two mappings: the first is made between the MR-MPS-SW (Reference Model of the MPS for Software) [6] and MPT-Br (Brazilian Test Improvement Model) [15]; and the second is made between the MR-MPS-SW and CERTICS models. With the results of his research, the author identifies that the first mapping showed a great adherence between the used models, while the second showed that MR-MPS-SW is not very much adherent to the CERTICS model. The gain is the compatibility verification between the models, favoring the implementation of the good practices that are present in an improvement program and the cost decrease in the individual implementation of each model, favoring a joint implementation.

The existence of several frameworks and papers that deal with the harmonization between practices present in different quality models favors the joint implementation and evaluation of those models, as well as helps the normative organisms to start to accept the existence of practices that are still not present in current versions of their models, facilitating the improvement of the organizational process without the need for intervention of several models in individual form.

III. RESEARCH METHODOLOY

The mapping between the CERTICS and CMMI-DEV models was based on the methodology by Araújo [8],

Who performed two mappings, between the MR-MPS-SW and MPT.Br models, and, the second, between MR-MPS-SW and CERTICS models. The work by Araújo [8] and this research have many similarities, due to the huge intersection between MR-MPS-SW and CMMI-DEV and the fact that one can be used to verify the other, with some treatments/adequations relating to the assets present in both models, as can be seen in [16].

Nevertheless, this paper is justified due to the importance of the implementation of the CMMI model for the national software industry. As can be seen in the website *https://sas.cmmiinstitute.com/pars/*, close to 100 evaluations were recorded in the last 4 years.

The mapping between the CERTICS and CMMI-DEV models occurred in a systematic way, through the execution of several well defined steps (see Figure 1), which allowed us to analyze both models and identify the main characteristics of each one of them. This allowed us also to map items that have a certain degree of equivalence between the models. This methodology required five steps, which will be detailed in this section.

First, we performed an analysis of the CERTICS and CMMI-DEV models, based on the CERTICS Evaluation Reference Model [7] and in the CMMI guide for development [3]. In this step we strove to understand the models and to identify its structures. With the analysis of the structures of both models, we identified that the models have different structures and that in order to perform the mapping it is necessary to identify the common structures for both models.

In order to perform this verification, we began the second step, which was called the definition of the meta-model, whose goal was to elaborate a meta-model containing the equivalent points in the structure of CERTICS and CMMI-DEV. In this step we verified through this model analysis that CERTICS is divided into four areas of competence and has 16 expected results, while CMMI-DEV é divided into 22 Process Areas, which are made of several Specific Practices and Generic Practices. In the next sections we will detail how the structural components of both models are related.

A. Definition of the Meta-Model

In spite of the different structures of each model, given the analysis we made of each one of them, it was possible to identify that some items were equivalent, as we identify and show in Figure 2, where you can seen both CERTICS and CMMI-DEV.

The CERTICS competence areas are equivalent to the CMMI-DEV Process Ares, because both are made of a set of practices (expected results) that, when used, end up satisfying the goals of the competence areas (in the case of CERTICS) or process areas (if the model at hand is CMMI-DEV).

The key questions of CERTICS are equivalent to the specific goals and generic goals of CMMI-DEV, because both describe the characteristics that must be found to satisfy the demands of the models.

The expected results of CERTICS correlate with the specific practices and generic practices of CMMI-DEV, because both detail what is expected as practice in each model. Each expected results, specific practice or generic practice characterizes a specific demand of the model. In the case of a generic practice, it can be applied to several process areas, the reason why it is considered to be generic. These correlations are well accepted in the area, given that they serve to avoid duplicate implementations of good practices existing in different models.

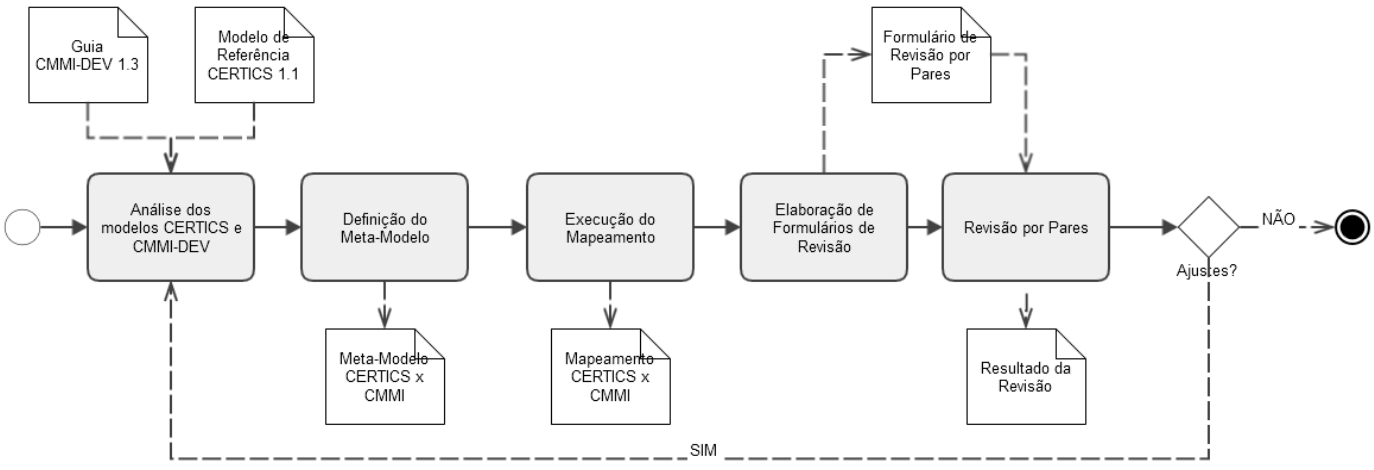

Fig. 1. Steps for the mapping between the CERTICS and CMMI-DEV models

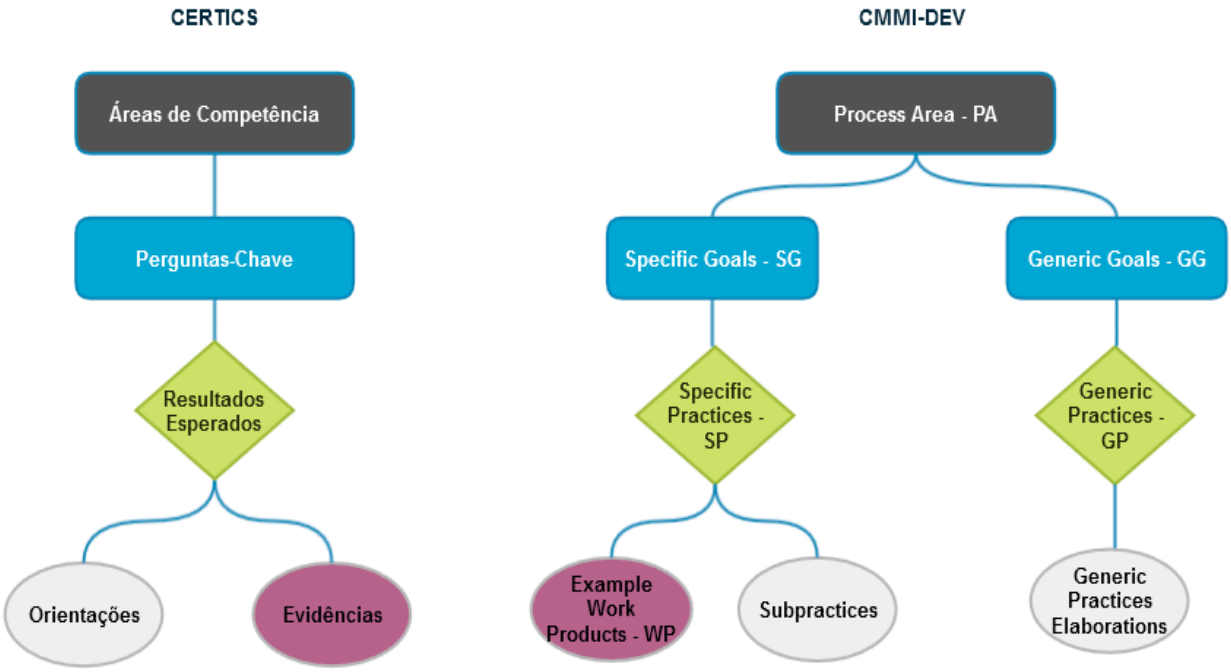

Fig. 2. Meta-Model CERTICS x CMMI-DEV. The equal colors symbolize equivalent elements between models.

The CERTICS guidances are equivalent to the *Subpractices* and *Generic Practices Elaborations* of CMMI-DEV, because they serve as a North to the model implementation process, offering guidance of how to implement each model item. Finally, we have the CERTICS evidence, which are equivalent to the Example Work Products from CMMI-DEV, which act as a reference base on what is expected in order to comply with each demand from each model.

Based on these fundamental concepts, Tables 1, 2, 3 and 4 below show the correlations between the CERTICS competence areas and the CMMI-DEV process areas. We can see in this correlation that there is not a single process area that is equivalent to a single competence area, because in order to comply with the expected CERTICS results, it is necessary to have a set of process areas from the CMMI-DEV model.

Because of space limitations, the full mapping document between the specific practices and the expected results is available at *http://cin.ufpe.br/~srbo/SPIDER_Mapeamento_CERTICSCMMI.doc*.

It is important to emphasize that we adopted CERTICS as the origin of this mapping because the reach of the expected results in its competence areas can be favored by many practice recommendations present in CMMI-DEV, that is, for the implementation of those practices, the CMMI-DEV model proposes in its guide, even if only with informative intention, the use of Subpractices, Generic Practices Elaborations and Example Work Products.

In order to contemplate the expected results from the Technological Development Competence are, the CERTICS model evaluation reference [7] recommends that the organizational unit complies with the following expected results:

- DES.1. Competence on architecture;
- DES.2. Competence on Requirements;
- DES.3 Phases and disciplines compatible with software;
- DES.4. Identified roles and persons;
- DES.5. Documented relevant technical data;
- DES.6. Competence for software support and evolution.

In order for CMMI-DEV to cover the expected resutls for the Technological Development Competence área, it is necessary to use the *Specific Practices* of 10 *Process Areas*, as shown in Table I.

The Technological Development Competence Area (DES) encompasses the mastering of the technologies present in the software product, in order for the organizational unit to apply the practices that show that it has the competence to develop, support and update the software product.

Table I. Correlation between the Technological Development Area x CMMI-DEV

CERTICS		***CMMI-DEV***		
SIGLA	**Competence Are**	**NÍVEL**	**SIGLA**	***PROCESS AREA***
DES	Technological Development	2	PP	*Project Planning*
		2	PMC	*Project Monitoring and Control*
		3	OT	*Organizational Trainning*
		3	TS	*Technical Solution*
		3	PI	*Product integration*
		2	REQM	*Requirements Management*
		3	RD	*Requirements Development*
		3	IPM	*Integrated Project Management*
		2	CM	*Configuration Management*

In this sense, using the CMMI-DEV practices we begin to cover the competence areas, because the CMMI-DEV process areas answer the technological development competence are in the following ways:

- *Project Planning* (PP) – allows us to perform the planning of data management and skills of the stakeholder so that only qualified professionals are involved in the project;
- *Project Monitoring and Control* (PMC) – Complements PP, allowing to perform monitoring of the human resources based on what was planned in PP. Besides performing monitoring, PMC contemplates the demands of CERTICS of identification of critical issues in the projects and in the implementation of corrective solutions for them;
- *Organizational Trainning* (OT) – Seeks to identify and supply training based on the needs identified in the organization, so that it is always seeking to qualify their professionals in the Technologies used in their projects;
- *Technical Solution* (TS) – This Process Area generates evidences that show that the organizational unit has competence on the relevant elements of the software product architecture;
- *Product integration* (PI) – Provides the correct treatment for internal and external interfaces, seeking to guarantee their compatibility. Besides, monitors and manages changes in those interfaces;
- *Requirements Management* (REQM) – Allows for the autonomy for each organizational unit to perform changes in the requirements in order to ensure that the project plan is always aligned with the requirements;
- *Requirements Development* (RD) – Offers CERTICS the definition and the documentation of the requirements, because it allows the establishment and maintenance of the product and its components requirements based on the clients requirements, identifying interface requirements and dealing with the refinement and the allocation of functional and non functional requirements;
- *Integrated Project Management* (IPM) – Establishes phases and disciplines compatibles with the software, because it allows for the integration of the project plan with other plans that affect it. Besides, it allows for the performance of the management based on the process defined by the organization;
- *Configuration Management* (CM) – Allows for the implementation in the organization of a configuration and data management system to ensure that the relevant project data are store safely and are available and easy accessible. The changes are then managed and auditing can be made on the system.

Another competence área of the CERTICS model is the Technology management, which has the following 4 expected results that should be made evident by organizational unit, according to the CERTICS Evaluation Reference Model [7]:

- TEC.1. Usage od research and technological development results;
- TEC.2. Appropriation of the relevant Technologies used in the software;
- TEC.3. Introduction of Technological Innovations;
- TEC.4. Decision capacity in the relevant software Technologies.

CMMI-DEV has specific Process Areas that contain Specific Practices related to the compliance of these expected CERTICS results, as illustrated by Table II.

Quadro II. Correlação da Área de Gestão da Tecnologia x CMMI-DEV

CERTICS		***CMMI-DEV***		
Acronym	**Competence Area**	**Level**	**Acronym**	***PROCESS AREA***
TEC	Technology management	2	PP	*Project Planning*
		2	PMC	*Project Monitoring and Control*
		3	OT	*Organizational Trainning*
		5	OPM	*Organizational Performance Management*

The CMMI process areas that support the Competence Areas of CERTICS are:

- *Project Planning* (PP) – This process area has practices that allow the planning by the professionals involved in the project based on their specialties, as well as plans the involvement of the stakeholders and the data management for the project;
- *Project Monitoring and Control* (PMC) –In technology management, this practice acts complementing the PP through the execution of the monitoring in the practices planned by the PP, as well as allowing for the project to be monitored against the plan;
- *Organizational Trainning* (OT) – This process area has the goal of identifying the needs for capacitation and the execution of training based on the identified needs. This practice allows the organizational unit to attest that the professionals have acquired the technological knowledge that is relevant to the software at hand;
- *Organizational Performance Management* (OPM) – This process area seeks to improve the organizational processes, because it allows for the identification, selection and implementation of improvements based on cost-benefit analysis.

The CERTICS Evaluation Reference Model [7] defined the Continuous Improvement Competence Area as composed by the following 3 expected results, whose compliance the organization must render evident:

- MEC.1. Hiring, training and incentive to qualified Professional;
- MEC.2. Dissemination of software related knowledge;
- MEC.3. Actions to improve processes.

O CMMI-DEV has 6 process areas that define specific practices whose goal is to comply with the expected results of the Continuous Improvement Competence Area of CERTICS, as shown by Table III.

Table III. Correlation of the área of Continuous Improvement x CMMI-DEV

CERTICS		***CMMI-DEV***		
Acronym	**Competence Area**	**Level**	**Acronym**	***PROCESS AREA***
MEC	Continuous Improvement	2	PP	*Project Planning*
		2	PMC	*Project Monitoring and Control*
		3	OT	*Organizational Trainning*
		3	OPD	*Organizational Process Definition*
		3	OPF	*Organizational Process Focus*
		3	OPM	*Organizational Performance Management*

- *Project Planning* (PP) – In Continuous Improvement, this process área allows for the planning of the skills so that only qualified professionals are involved with the project;
- *Project Monitoring and Control* (PMC) – Allows the monitoring to be performed based on the real values of the parameters that were planned in the project, as well as the management of the data;
- *Organizational Trainning* (OT) – Seeks to identify, establish and maintain training projects based on the organizational needs, besides keeping records of the efectivity of those trainings;
- *Organizational Process Definition* (OPD) – in Continuous Improvement, this process área seeks to establish and maintain a description of the needs and organizational goals;
- *Organizational Process Focus* (OPF) – With this process área the organization starts to identify improvements for the processes and assets of processes in the organization, besides establishing and maintaining plans to implement those improvements and to execute them when needed;
- *Organizational Performance Management* (OPM) – This process área seeks to keep the business goals based on the understanding of the organization business strategies and the current performance, results.

The Business Management Competence Area of the CERTICS model defines the following 3 expected results which need to be achieved by the organization [7]:

- GNE.1. Market Monitoring Actions;
- GNE.2. Antecipation and Compliance with Client Needs;
- GNE.3. Evolution of the Software Related Business.

These expected results are related to the management of actions related to the potential market of the software products. In this sense, the CMMI-DEV does not cover any of the results of the Business Management, because the focus of CMMI-DEV is the development process of the software products, as can be seen in Table IV.

QUADRO IV. Correlation of the Area of Business Management x CMMI-DEV

CERTICS		***CMMI-DEV***		
Acronym	**Competence Area**	**Level**	**Acronym**	***Process Area***

GNE	Business management	X	X	X

Nevertheless, CMMI-DEV does not have any process área whose goal is related to the administration of practices related to the increase of knowledge based business, from the software, such as actions to monitor the market trends; Hence, CMMI-DEV does not comply the Business Management Competence Area, given that CMMI-DEV focus on the improvement of the software development process, not in market analysis. A possible model that could complement this adherence would be the CMMI-Services model, which is a CMMI Reference Model that covers the activities of any type of service offer and management, and contains practices that include Project Management, Process Management, Service management and other support practices used in service offer and management.

B. Definition of Coverage Criteria and Mapping Spreadsheet

We adopted the following classification criteria from Araújo [8] to our mapping:

- **Covered – COB:** the situation in which CMMI-DEV complies with all the requirements of the CERTICS expected result;
- **Partially Covered – COB -:** the situation in which CMMI-DEV complies with some or several of the requirements of the CERTICS expected result;
- **Not Covered – NÃO:** the situation in which CMMI-DEV does not comply with the requirements of the CERTICS expected result.

After choosing the criteria to be used in the mapping, we saw the need to standardize the way the information in the models would be analyzed and stores. Hence, a model document for information evaluation and storage was create, allowing us to standardize the analysis of the CERTICS and CMMI-DEV models, as illustrated by Table V.

Once again we used CERTICS as the origin of the mapping. Hence, the tables will have a single line at the first columns, corresponding to the competence area or expected result that is being mapped. This line will be mapped to several elements in CMMI-DEV that can be mapped and effectively cover the element at the first column.

Table V. Document Modelo f the Mapping as used in the rest of this paper.

CERTICS	***CMMI_DEV***				
Competence Area/ Expected Results	**CMMI Coverage**	**Level**	***Process Area***	**Acronym**	***Specific Practices/ Generic Practices***
Competence Area/ Expected Result	Classification of coverage	Level of the process area	Name of the *Process Area* or of the *Generic Practice*	Acronym of the Process Area	Name of the *Specific Practice* da *Process Area*

The model document presented in Table V allows us to detail the structure of the CERTICS model in a way that the expected results from each competence area are described and detailed, as well as showing the guidelines for how to comply with their requirements.

In terms of CMMI-DEV, the document allows us to define a classification of the coverage of CMMI-DEV in relation to the CERTICS model. Besides, it is possible to add which specific practices of a specific process area conform to the CERTICS expected result, allowing us to describe the way the CMMI-DEV specific practice comply with the CERTICS expected results.

IV. MODEL MAPPING

The model mapping was performed according to the criteria defined by Araújo [8], using the standard mapping document presented in sub-section B of section III of this work. For this, all the Competence Areas of the CERTICS model were analyzed and compared with the process areas from CMMI-DEV, so that the CERTICS expected results were contemplated with the CMMI-DEV specific practices.

Table VI presents a sample of the mapping between the CERTICS and CMMI-DEV models where the DES1 expected result from the Technological Development Competence Area is correlated with the specific practices from the Organizational Training, Product Integration, Project Monitoring and Control, Project Planning, Technical Solution Process Areas and with Generic Practice 2.5. The complete mapping document is available at the web address http://cin.ufpe.br/~srbo/SPIDER_Mapeamento_CERTICSCMMI.doc. In this document you will find a description of each Specific Practice and of the Process Area that were used in this relationship.

Table VI. Mapping of the Expected Result for DES 1 to CMMI-DEV

CERTICS	***CMMI-DEV***				
Competence Area/ Expected Results	**CMMI Coverage**	**Level**	***Process Area***	**Acronym**	***Specific Practices/ Generic Practices***
Technological Development (DES1): Competence on Architecture.	COB -	2	*Generic Practices*	GP	GP.2.5
		3	*Organizational Trainning*	OT	OT.SP.1.1
					OT.SP.1.2
					OT.SP.2.1
					OT.SP.2.2
					OT.SP.2.3
		3	*Product integration*	PI	PI.SP.2.1
					PI.SP.2.2
		2	*Project Monitoring and Control*	PMC	PMC.SP.1.1
					PMC.SP.1.4
					PMC.SP.1.5
		2	*Project Planning*	PP	PP.SP.2.5
					PP.SP.2.6
		3	*Technical Solution*	TS	TS.SP.1.1
					TS.SP.1.2
					TS.SP.2.1
					TS.SP.2.2
					TS.SP.2.3
					TS.SP.2.4
					TS.SP.3.1
					TS.SP.3.2

The mapping results were very important, because they allowed us to identify which elements from CMMI-DEV complied with the requirements of the CERTICS model. We could also quantify the CMMI-DEV elements that were in conformity with each of the CERTICS expected results. In order to show this, the graph in Figure 3 shows the Technological Development Competence Area and the compliance of each of its expected results by the CMMI-DEV practices.

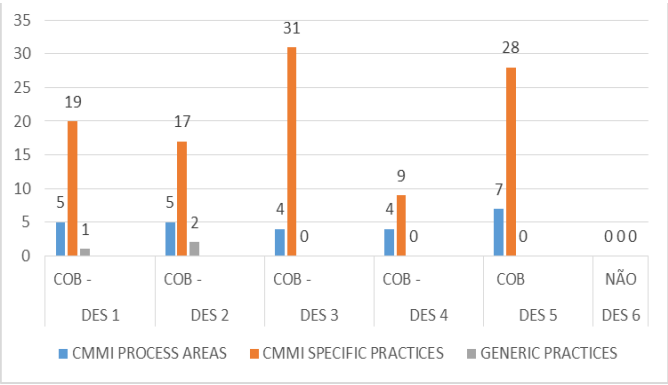

Fig. 3. Compliance with the Expected Results of Technological Development.

The expected result DES-1 is partially covered (COB-) by CMMI-DEV with 5 process areas which are related to 19 specific practices. Besides, CMMI-DEV has a generic practice that is related to the CERTICS expected result. The coverage by CMMI-DEV was not full, because there are some demands present in the CERTICS model that are not dealt with by CMMI-DEV, such as: the responsible parties for the architecture must be hired by the CLT regime (the official hiring practice in Brazil), or must be partners in the organization and be currently living in the country. In the subject of software acquisition and/or the team that developed it, CMMI-DEV does not make demands on the autonomy for decision making or to perform updates in those acquired components, and does not make any demand that the purchased component was updated.

The expected result DES-2 is partially covered (COB-) by 5 process areas, which have 2 specific practices and 2 generic practices that allow for a partial coverage of the expected result. As in the case of DES-1, the coverage was not full because CMMI-DEV does not make demands related to the residence of the professionals responsible for the architecture, or to the fact that they are hired through the CLT model or are partners in the company. CMMI-DEV also does not make demands on updates on purchased components or the proof that these components were actually updated.

DES-3 is partially covered (COB-) by 4 process areas and 31 specific practices. The coverage is not full because of the same exigencies in DES-1 and DES-2 that are not contemplated by CMMI-DEV.

DES-4 is equally partially covered (COB-) by 4 process areas and 9 specific practices of CMMI-DEV. Coverage is not full, because this expected result references the identification of the professionals involved in the support and product evolution activities, but the support activity is not dealt with in CMMI-DEV, because it focuses only on the product development and evolution.

DES-5 is covered (COB) by 7 process areas and 28 specific practices of CMMI-DEV. The CMMI-DEV practices that were related to this CERTICS expected result allowed for full compliance with its requirements.

Finally, there is DES-6, which was not covered by any practice from CMMI-DEV, because this expected result makes demands related to product support and evolution, which is not listed in any practice of CMMI-DEV.

In the Technological Management competence area, we have four expected results (TEC-1, TEC-2 TEC-3 and TEC-4), which were represented in the graph in Figure 4, showing the number of CMMI-DEV practices that comply with the expected results of this competence area.

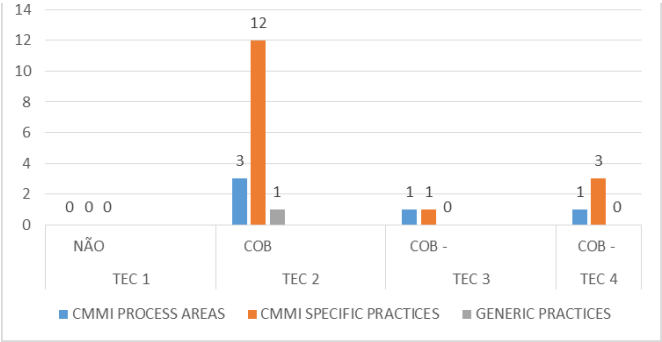

Fig. 4. Compliance to the Expected Results of Technological Management.

The first expected result, TEC_1, was not covered by CMMI-DEV, because the model does not demand using research and technological development results in its implementation. In order to comply with this expected result, it would be necessary for practices of CMMI-DEV to guarantee the usage og technological resources such as technical solution definition projects based o R&D (Research and Development), partnerships or indicators of investment in R&D related to the software product.

TEC-2 was covered (COB) by 3 process areas, 12 specific practices and 1 generic practice, complying with all the demands of this CERTICS expected result.

TEC-3 was partially covered (COB-) by CMMI because the model has one process area (OPM – Organizational Performance Management) and one specific practice (SP2.1 – Elicit Suggested Improvements) that comply with the demands of this result.

It is important to point out that in order for the TEC-3 result be fully complied with, according to [7], it is necessary to verify if the organizational unit has an innovative culture, if it gives incentive to its professionals in the seek for ideas that are innovative and if any technological innovation was implemented or improved in the software. It is necessary to find information that shows that actions were taken to implement or improve this innovator software aspect.

Aligned to this goal is SP2.1 of OPM which, according to [3], focuses on bringing the suggestedi mprovements and includes the categorization of those improvements as incremental or innovative. The innovative ones may be a consequence of a systematic search for solutions for the specific performance problems or only ooportunities to improve the performance.

Nevertheless, compliance was not full, because CMMI-DEV does not have practices for the offering of bonifications for professionals that created proposals of technological innovation. Another demand that was not complied with was the inclusion of innovative ideas that are a result from joint work with R&D teams, as well as the finalization of software with technological innovation.

TEC-4 was also partially covered (COB-) by CMMI-DEV, with one process area and 3 specific practices related to the compliance of the demands of this CERTICS expected result. Nevertheless, compliance was partial because in spite of the fact that CMMI-DEV has practices that allow to analyse suggested improvements, select which will be implemented and validate the improvements, this model does not make demands on the evidence that attest to the execution of the updates in relevant technologies present in the software that would come from a decision from an organizational unit.

The Business Management Competence Area has three expected results, which are directed to the execution of market monitoring actions (GNE-1), client needs antecipation actions (GNE-2) and software related business evolution (GNE-3). In this context, the CMMI-DEV area does not have any process area that complies with these demands from the CERTICS model, given that its focus is not in the administrative issues. Hence, the three expected results are not covered by CMMI-DEV, as shown in the graph in Figure 5.

Finally, the Continuous Improvement Competence Area has three expected results (MEC-1, MEC-2 and MEC-3), which were related to CMMI-DEV as shown in the graph in Figure 6.

The expected result from MEC-1 was partially covered (COB-) by 3 process areas, 11 specific practices and one generic practice from CMMI-DEV. This expected result was partially covered because CMMI-DEV makes no demands on the execution of incentive programs from the professionals in the organization. Another item not complied with by CMMI-DEV is the demand for verification of actions towards the hiring and training of professionals for the activities related to business and technological development, support activities and software evolution.

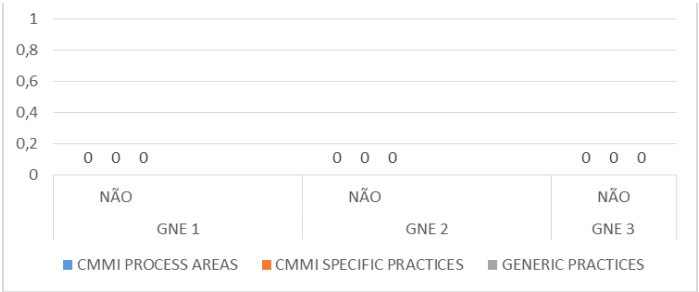

Fig. 5. Compliance to the Expected Results for Business Management.

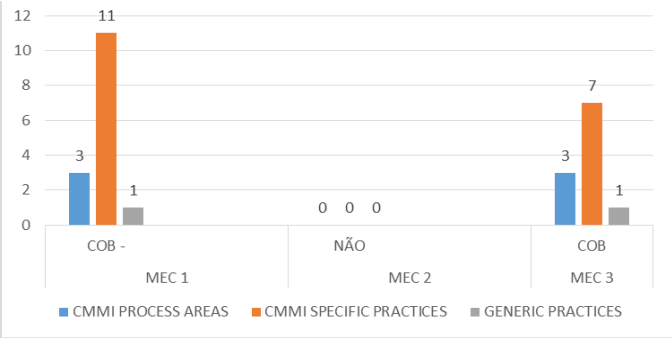

Fig. 6. Compliance to the Expected Results for Continuous Improvement.

MEC-2 has the goal of dissemination of the knowledge generated in the development of the software product and in the business activities present in the software. These practices are not covered in the CMMI-DEV model, hence this expected result was classified as non covered (NÃO). This is due to the fact that the CMMI-DEV does not have practices related to knowledge management such as: planning and establishment of a strategy for knowledge management, creation of an expert network and making available and sharing the knowledge. The closest are in the CMMI-DEV related to the practices of knowledge management deal with organizational training, whose goal is to offer subsidies to develop the skills and knowledge of the personnel so that they can execute their roles in an efficient and effective way, but does not deal with management of the knowledge gathered by the personnel during project development , as can be seen in [11]. This way the organization that adopts CMMI-DEV will not have practices in its work processes related to this management area, contemplated with the adoption of the CERTICS model, which consists in a good justification for the harmonization work presented in this paper, between two different models of product and process quality.

MEC-3 was covered (COB) by CMMI-DEV by 3 process areas, 7 specific practices and one generic practices. The practices of CMMI-DEV that were related to this expected result allowed for the verification that actions for the improvement of processes are undertaken, complying fully with this expected result.

V. Peer Review

In order to evaluate the research performed, the peer review technique was used, calling for the help of an expert in the CERTICS and CMMI-DEV models. The evaluator was chosen because of his thorough knowledge in both models. The profile of the evaluator that performed the peer review showed that he possesses certifications in both CMMI-DEV and CERTICS, besides showing a deep knowledge on reference models for software products and process, having worked for more than 5 years with the implementation of improvement models for software process or product in organizations.

Next, we performed the definition of the goals of the peer review, which had the goals of verifying the following items:

- The meta-model correlated adequately the structures of CERTICS with CMMI-DEV.
- The CERTICS competence areas are adequately related to the CMMI-DEV process areas.
- The CERTICS expected results are adequately related to the CMMI-DEV specific practices.
- The comparison criteria used in the descriptions are adequate.

In order to standardize and organize the task of peer review, we created a model form that contains the following evaluation criteria in order to define a classification of rach doubt or inconsistence found in the mapping:

- **TA (Technical High)**, indicates that we found a problem in an item that, if not altered, Will compromise the considerations.
- **TB (Technical Low)**, indicating that we found a problem in an item which would be convenient to change.
- **E (Editorial)**, indicating that we found an error in the language of text or that the text itself can be improved.
- **Q (Questioning)**, indicating that there were doubts on the considerations.
- **G (General)**, indicating that the comment is general in relation to the considerations.

Given the ideas above, with the goals and criteria for peer review defined, we delivered to the evaluator the document mapping the two models (available at *http://cin.ufpe.br/~srbo/SPIDER_Mapeamento_CERTICSCMMI.doc*); the peer review form, which contained the criteria to perform the review (available at *http://cin.ufpe.br/~srbo/SPIDER_FormularioRevisaoPorPares_CERTICSCMMI_NaoPreenchido.doc*); as well as a confidentiality term, where the reviewer allows us to use the information related to the research in a way that his anonymity is preserved (available at the web address *http://cin.ufpe.br/~srbo/SPIDER_TermoConfidencialidade.docx*).

After receiving the material, the specialist began reviewing the materials and the problems he identified were recorded in the peer review form. At the end of the review, the specialist returned the mapping document, athe peer review form filled with his observations (available at the web address

http://cin.ufpe.br/~srbo/SPIDER_FormularioRevisaoPorPares_CERTICSCMMI_Preenchido.doc) and the confidentiality term duly signed.

The problems identified in the peer review (Technical High, Technical Low, Editorial, Questioning and General) were analyzed and tabulated, which allowed us to create the graph in Figure 7.

We identified: 4 Technical High Problems, 8 Technical Low problems, 1 Editorial problem and 1 general problem. The reviewer did not classify any problem as Questioning (Q). In the expected results DES-1, DES-2, DES-4 and MEC-1 were identified problems classified as Technical High. In the expected results DES-1, DES-2, DES-3, TEC-2, MEC-1 and MEC-3 were identified problems classified as technical low. The items that were identified as general and editorial are related to the descriptions of some items of the mapping document, such as the meaning of the specific practices and the descriptions of the coverage criteria.

This way, the considerations made by the reviewer in each identified problem were analyzed in order to verify whether or not they would be acceptable. After analyzing all the considerations made by the expert, we decided that all of them should be accepted, as shown in the graph in Figure 8 and the items where problems were identified were duly corrected.

In the items classified as technical high, one specific practice was listed incorrectly in four CERTICS expected results. This way, it was recommended to change the CMMI-DEV specific practice that was not actually complying with the CERTICS expected results. The practices was SP 1.4 of the process area PMC, which should be modified to practice SP 1.5 of the same process area.

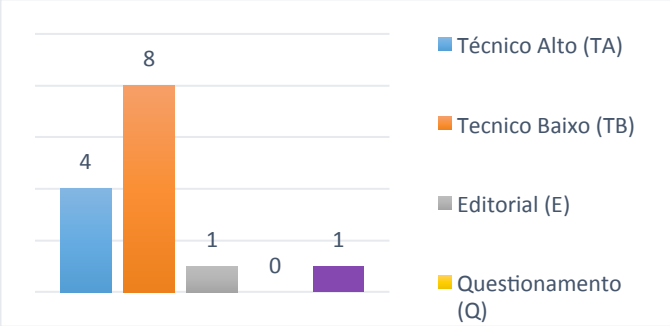

Fig. 7. Problems identified after Peer Review

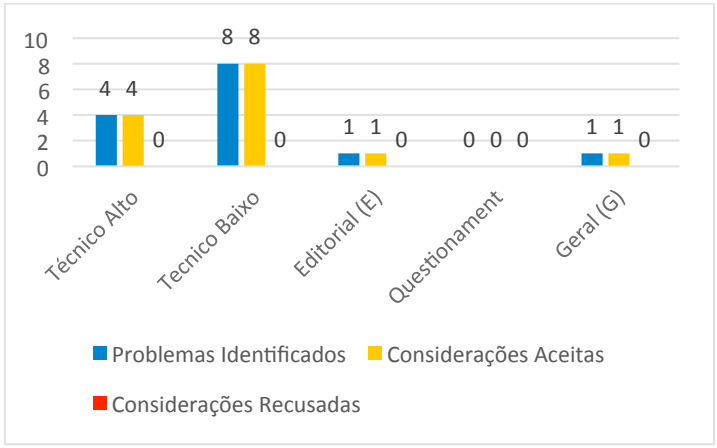

Fig. 8. Considerations accepted/refused X Problems identified after Peer Review

The recommendation on the problems classified as technical low were related to adjustments in the justifications for inclusion of some CMMI-DEV specific practices, as well as some adjustments in the acronyms and/or names of those practices, because some were incomplete. The practices were GP 2.2, 2.4 and the practice SP 2.4 of the process PP.

The problems that received classification General consist on the analysis of the material as a whole, for the elimination of duplicated and/or incomplete items. Finally, the problem described as Editorial is related to the description of coverage criteria (COB and COB-), and it was recommended to adjust the description of those criteria.

In Table 7 we present the problems that were identified in the mapping between CERTICS and CMMI-DEV, where the columns present the type of problem found in each of the CERTICS expected results (represented in the table lines).

Table VII. Problems found in the Mapping by Expected Result

Criteria	*Technical High (TA)*	*Technical Low (TB)*	*Editorial (E)*	*Questioning (Q)*	*General (G)*
COB, COB -	0	0	1	0	0
DES 1	1	2	0	0	1
DES 2	1	2	0	0	1
DES 3	0	1	0	0	1
DES 4	1	0	0	0	1
DES 5	0	0	0	0	1
DES 6	0	0	0	0	1
TEC 1	0	0	0	0	1
TEC 2	0	1	0	0	1
TEC 3	0	0	0	0	1
TEC 4	0	0	0	0	1
GNE 1	0	0	0	0	0
GNE 2	0	0	0	0	0
GNE 3	0	0	0	0	0
MEC 1	1	1	0	0	1
MEC 2	0	0	0	0	1
MEC 3	0	0	0	0	1

The expected result DES-1 showed one TA type problem, because the specialist identified that the mapping of this result was incomplete, because there was one specific practice from CMMI-DEV that had not been related to this result. Hence, he recommended the inclusion of specific practice PMC SP 1.5, whose goal is to monitor the project stakeholders. In this expected result, the reviewer also found 2 TB type problems, the first related to the absence of name for a generic practice, which was related to this expected result and the second related to the absence of description for a specific practice which was related to the DES-1 result.

For DES-2 he identified one TA-type and 2 TB-type problems. The TA problem was an incorrect association of a specific practice (PMC SP 1.4), whose goal is to monitor de project data management, but in DES-2 the focus in the organization unit competence over the relevant software requirements. Hence, the reviewer suggested the change from practice PMC SP 1.4 to PMC SP 1.5, whose goal is to involve the project stakeholders. The first TP-type problem in DES-2 indicated that one specific practice was described erroneously and the second was related to a explanation of expected result coverage that was not correct. Hence, the reviewer suggested that both problems should be corrected.

The expected result DES-3 presented one problem similar to the one found in DES-2, which was also classified as TB, because in this result we also found incoherence in the coverage justification, becoming necessary an adjustment in it.

In the expected result DES-4, the identified problem was classified as TA, because there was an error in one specific practice that had been mapped, given that this results requests the analysis of roles and persons and the specific practice PMC SP 1.4 seeks to monitor the project data management. Hence, the reviewer suggested changing from PMC SP 1.4 to PMC SP 1.5, whose goal the involvement of the project stakeholders.

In TEC-2 the reviewer found one problem classified as TB, for in this expected result one generic practice had no name, and he suggested that its name was included in the mapping document.

The reviewer identified two problems in MEC-1 which were classified respectively as TA and TB. The TA-type problem was the same identified in DES-4, making it necessary to change the CMMI specific practice from PMC SP 1.4 to PMC SP 1.5. The problem classified as TB was the same one than in TEC-2, that is, we lacked the name of a specific practice, which was duly included in the document.

Finally, in the expected result MEC-3, the reviewer identified that we lacked the name of one generic practice. Hence, he recorded the existence of a TB-type problem in this result, which made us include the absent name.

VI. Final Considerations

Considering the nature of this research, we must stress the importance of works whose goal is to provide help to the decision making process in software developing organizations, in order to facilitate their analysis and adoption of the model or norm that is more adequate to its needs.

This work presented the mapping between two certification models: CERTICS and CMMI-DEV. In order to achieve its goals, this research sought to identify the similarities and the divergences between the structures of both models by mapping one to another.

In order to avoid understanding problems and inconsistencies, the mapping was evaluated by an expert in both models using the peer review technique. The results of the model review were analyzed and the suggested modifications were implemented in order to eliminate the inconsistencies and the understanding problems identified by the expert. The full mapping review generated after peer review is available at the web address *http://cin.ufpe.br/~srbo/SPIDER_Mapeamento_CERTICSCMMI.doc*.

The lesson learned when executing this research come from its analytic character and the comparison it makes between models. This way, it is interesting that this kind of research be performed by more than one researchers, so that eventual conflicts and doubts be discussed and solved through peer review.

One of the limitations of this work is that the mapping has not been yet evaluated in a real software development scenario, having been analyzed solely by peer review. A mapping evaluation in a real scenario would allow us to identify how much the mapping contributed positively or negatively to a multi-model implementation.

Another limitation comes from the fact that the peer review was performed by a single specialist, which may cause a limited view of the results achieve in the research. Nevertheless, this specialist is part of the CERTICS specification group, and has long experience in the implementation of CMMI-DEV, which decreases the bias in the review result. The need for a new review is due to the subjective character in the understanding of the mapping performed between both models.

In the future, we intend to continue the evolution of this research, with the goal of applying it to a real scenario, allowing us to quantify the positive and negative points of using the mapping in a multi-model implementation that includes CERTICS and CMMI-DEV.

This application is already under way in an

organization in Belém-PA which has its processes defined according to the practices of CMMI-DEV level 2. Until now, we saw the following advantages of this joint implementation:

- Time and cost reduction for comply with the expected results and practices in the CERTICS and CMMI-DEV models;
- Generation of unified and standardized evidence to achieve both certifications;
- Standardization of the technical languages of both models for the definition of the software development process.

Another future work is the definition of the complete cycle of result harmonization between this research, the work by Araújo [8] and the SOFTEX guide [16].

Finally, it is worth mentioning that in spite of the similarities with the work by Araújo [8], this research discovered the following two differences in coverage between our works:

- In TEC-3, where it was detected that this result has partial coverage by practice SP 2.1 of the CMMI-DEV OPM process area. This is due to the fact that this practice requires the elicitation and categorization of the improvements suggested as innovations for the software; and
- In MEC-2, there is no coverage by CMMI-DEV, because this model does not propose the implementation of good practices related to knowledge management.

These difference showed that in spite of the fact that the models studies in both works (CMMI-DEV and MR-MPS-SW) are compatible, we can see that the level of demand from the practices in both models are not always equals, which makes this work different from the one performed by Araújo [8].

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REFERENCES

[1] Cordeiro, A. G.; Freitas, A. L. P. Priorização de requisitos e avaliação da qualidade de software segundo a percepção dos usuários. Ciência da Informação, v. 40, n. 2, 2012.

[2] itSMF UK. An Introductory Overview of ITIL® 2011. The IT Service Management Forum UK. Londons, 2011.

[3] SEI. CMMI for Development (CMMI-DEV). Version 1.3. Software Engineering Institute, Carnegie Mellon University. Pittsburgh, PA, 2010.

[4] ISO/IEC. ISO/IEC 15504-2: Information Technology - Process Assessment - Part 2 -Performing an Assessment. Geneve, 2003.

[5] Tennant, G. Six Sigma - SPC e TQM in Manufacturing and Services. Gower Publishing. Burlington, 2001.

[6] SOFTEX. Melhoria do Processo de Software Brasileiro (MPS.BR) - Guia Geral 2012. Brasil, 2012.

[7] CTI Renato Archer. Modelo de Referência para Avaliação da CERTICS - Documento de Detalhamento. Centro de Tecnologia da Informação Renato Archer. Campinas, 2013.

[8] Araújo, L. L. Mapeamento do MPS.SW com os modelos MPT.BR e CERTICS. Dissertação de Mestrado - UFRJ/COPPE. Orientadora: Ana Regina Cavalcanti da Rocha. Rio de janeiro, 2014.

[9] Baldassarre, M. T.; Caivano, D.; Pino, F. J.; Piattini, M.; Visaggio, G. Harmonization of ISO/IEC 9001:2000 and CMMI-DEV from a theoretical comparison to a real case application. Springer Science+Business Media. 20:309-335, 2011.

[10] Pardo, C.; Pino, F. J.; García, F.; Velthius, M. P.; Baldassarre, M. Trends in Harmonization of Multiple Reference Models. Springer-Verlang Berlin Heidel-berg, CCIS 230, pp. 61-73, 2011.

[11] Pelsdzius, S.; Ragaisis, S. Comparison of Maturity Levels in CMMIDEV and ISO/IEC 15504. Applications of Mathematics and Computer Engineering. Pages 117-122, 2011.

[12] Furtado, J. C.; Oliveira, S. R. B. A Process Framework fot the Software and Related Services Acquisition Based on the CMMI-ACQ and the MPS.BR Acquisition Guide. IEEE Latin America Transactions. No 6, 2012, Vol. Vol.10, 2012.

[13] García-Mireles, G. A.; Moraga, M. Á.; García, F.; Piattini, M. Towards the Harmonization of Process and Product Oriented Software Quality Approaches. Springer-Verlag Berlin Heidelberg. D. Winkler, R.V. O' Connor and R. Messnarz (Eds.), Vols. EuroSPI 2012, CCIS 301, pp.133-144, 2012.

[14] Garzás, J.; Pino, F. J.; Piattini, M.; Fernandez, C. M. A Maturity Model for the Spanish Software Industry based on ISO Standards. Elsevier B.V. 35, 2013, Vols. 616-618, 2013.

[15] SOFTEX RECIFE. MPT.Br Melhoria de Processo de Teste Brasileiro - Guia de Referência do Modelo. s.l. : SOFTEX RECIFE, 2011.

[16] SOFTEX. Guia de Implementação – Parte 11: Implementação e Avaliação do MR-MPS-SW:2012 em Conjunto com o CMMI-DEV v1.3. Brasil, 2012.

[17] Governo Federal – Casa Civil. Decreto n. 8.186 de 17 de Janeiro de 2014. Brasil, 2014. Disponível em: *http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2014/decreto/d8186.htm*. Último Acesso: Novembro/2015.