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TRILHA PRINCIPAL

# A Mapping Model Applied to the IT Solutions Procurement Guide of the Normative Instruction IN SLTI MPOG 04/2014 and the Models Constellation CMMI-ACQ, CMMI-DEV e CMMI-SVC

Luiz Sérgio Plácido da Silva[1], Suzana C.B. Sampaio[2], Renata Teles Moreira[3] e Alexandre M. L. Vasconcelos[4]

***Abstract*** - Several initiatives have emerged in the search for improvement of software processes in recent years. These initiatives are usually guided by Standards, Models and Quality Standards, aiming to establish best practices to guide the definition of processes and support the assessment of the maturity and capacity of organizations in the development of software products and provision of IT services. Despite the emergence of several initiatives, when the topic refers to the processes of contracting information technology (IT) solutions by the Brazilian Federal Public Administration (APF), its application in the context of organizations has obstacles, such as the complexity of the processes and oversight of federal government agencies. In order to overcome these obstacles, the Court of Audit of the Union (TCU) recommended the preparation of the SLTI/MPOG 04/2014 Normative Instruction, containing guidelines for the process of contracting IT Solutions. This work defines a Mapping Method between IN/SLTI/MPOG 04/2014 and APF's IT Solutions Procurement Guide (GCSTI), with the objective of identifying the maturity and adherence of GCSTI to CMMI-ACQ, CMMI -DEV and CMMI-SVC. This work defines a Mapping Method between IN / SLTI / MPOG 04/2014 and its processes defined in the APF IT Solutions Procurement Guide (GCSTI), with the objective of identifying the maturity and adherence of the GCSTI to the Models CMMI-ACQ, CMMI-DEV and CMMI-SVC and bringing as benefits a systematized and structured methodology to apply and map models, norms and standards of any nature. As a result of this research, the mapping method created allowed the mapping between the CMMI and GSTI models of IN / SLTI / PMO 04/2014, and the method could be applied in any other mapping, from which the processes were oriented to the same Structure and had similar objectives.

***Keywords:*** Processes, Hiring IT Solutions, CMMI Models.

1 - Estudante de Doutorado em Ciência dá Computação - CIn/UFPE - lsps@cin.ufpe.br
2: Suzana C. B. Sampaio - Professora - DEINFO/UFRPE - suzana.sampaio@gmail.com
3 - Renata Teles Moreira - Professora - DCC/UFLA - renatatm@gmail.com
4 - Alexandre M L Vasconcelos - Professor - CIn/UFPE - amlv@cin.ufpe.br

## I. Introduction

Recently there has been a growth in IT services (IT) and a larger reliance on them. Among those services we can include customer support, data storage and the creation of the infrastructure needed to support different technologic resources needed by the customers. Hence, IT service providers are challenged to supply to these ever present demands, so hat hey can continue to be competitive in their markets and to adhere to the quality expectations their clients have [1], [2], [3], [4], [5], [6], [7].

There have been several different researches that try to understand the factors that affect the quality of the IT services provided. These researches intend to understand which aspects can be improved to comply with the clients' needs and expectations, which are ever growing [6], [7].

In spite of the existence of several researches on the IT services quality, it is clear that the identified perceptions and needs happen reactively, that is, there are flaws in how providers address important aspects that affect IT services quality in a preventive way. That means that we lack business strategies that include management, planning and training issues that take this issues into account in a critical way, for the identification and perception of the clients requirements and needs. This is worsened by the fact that the latter are ever more demanding, given the emerging scenario in which they are inserted [7], [8].

Based on the existing studies and researches, we can see several flaws in the adoption of the consolidated best practices all over the world, even if they are proactive, planned and structured and IT service management and operation oriented [7], [8], [9], [15], [21], [23], [24], [25], 26], [27].

The adoption of IT service providing best practices is relevant. We must consider, for a better performance of the service providers, both management and processes, quality, clients and their businesses, always having in mind their satisfaction and contributing to the increase of the

competitiveness and of their profits [11], [12], [13], [14], [31].

In a similar way to the situation of several other industry areas, quality is a key and critical issue for the IT Services sector [14], [7], [15], [27]. In order to increase the companies competitiveness and the offer capacity for quality IT services and products, both in the national and international arena, it is essential that the IT Service providers are aligned with the efficiency and efficacy of the processes, focusing on the clients and on their businesses.

Hence, we have as goal the IT service offer according to normative standards and quality models that are worldwide accepted [7], [15].

We can also highlight the Brazilian Federal Government, through the Brazilian Federal Public Administration (APF) is the largest Brazilian consumer of IT services and goods [4], [7], [16], [19]. Besides, there is a law bill that determines that operational and execution activities are performed mainly by third parties.

Even though the departments that comprise the APF have made several moves, their performance in the management and execution of contracts have been subject to many problems, such as the complexity of the Brazilian law [7], [15]. Hence, there are frequent difficulties in the execution of contracts, even when the recommendations are strictly followed. According to [7], [15], [23], [27], part of the problems is related to the APF laws and norms compliance. Nevertheless, we can see the difficulties faced by the government when dealing with processes that rule the procurement of IT services.

The reports made by the Union Accounts Court (TCU) show an excess expenditure by the APF, which may be a consequence of the complexity of the procurement processes for both the management and offer of IT services. An important fact that deserves attention in the context of researches related to IT services providing to the APF is that this may be even more challenging to the sector, given that 94% of the Brazilian IT companies can be defined as either micro or small companies (MPES) and depend directly or indirectly from the government to remain in the market [8].

In this context, we present a mapping between the IT Solutions Procurement Guide (GCSTI) from the Normative Instruction IN/SLTI/MPOG 04/2014, using as starting point the version 1.3 of the Models Constellation CMMI-ACQ, CMMI-DEV and CMMI-SVC. Our goal is to evaluate the maturity demanded by the IT services procurement process for the APF. Hence, a mapping method was created in order for the evaluation to be performed objectively.

This mapping will cause a positive impact on works and researches whose goals are either equal or similar to ours, given that once a model mapping method is described and applied, it can be applied in any mapping process, according to the goals of the research at hand.

This paper is organized as follows. After this introductory section, we have Section 2, which presents the bibliographic review we performed, Section 3, presenting the Research Methodology, Section 4, which shows the research execution, and finally, Section 5, which presents our conclusions at the end of this research.

## II. Bibliographic Review

### *A. IT Solutions Procurement Guide and the Normative Instruction IN/SLTI 04/2014*

In order to normalize the procurements related to IT solutions, the IT Solutions Procurement Guide (GCSTI) was created based on the process phases described in the Normative Instruction 04/2014 of the Secretary for Logistics in Information Technology (SLTI) of the Ministry for Planning, Budget and Management (MPOG).

The GCSTI is a set of processes for the procurement of IT solutions by the Brazilian Federal Public Administration (APF) which implements the processes, activities and tasks described in IN/SLTI/MPOG 04/2014 [21], [24], [25], 26], [27], through phases that unfold during the whole hiring process.

The GCSTI has three phases: (i) Planning of the IT Solutions Procurement (PCTI); (ii) Selection of IT Solutions Vendor (SFTI); (iii) Management of the IT Solution Contract (GCTI).

The procurement planning phase seeks to identify the need for the procurement, considering the strategic goals and the business needs of the institutions, as well as its alignment to the IT planning document. In this phase, the stakeholders responsibilities, justifications, expected results and funding sources are defined with care [21], [24], [25], 26], [27].

In the Vendor Selection phase, the IT area supports technically the Bidding Commission by answering its questions or defending itself against legal resources impetrated or even in the analysis and judgment of the biddings offered and of the appeals impetrated by each bidder [21], [24], [25], 26], [27].

The IT Solution Contract Management phase seeks to follow up and guarantee the correct execution of the services and the asserts supply that comprise the IT solution during the whole contract execution time frame [21], [24], [25], 26], [27]

The GCSTI phases are shown in Figure 1.

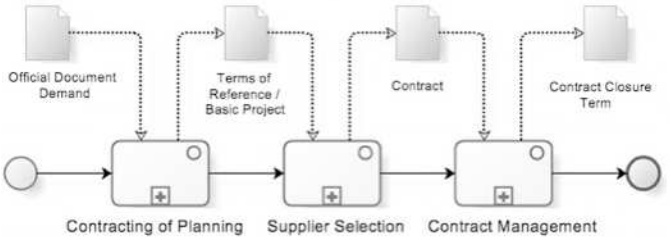


**Figure 1. The phases of the process of procurement of solutions in Information Technology [16].**

### *B. CMMI Models*

The CMMI (*Capability Maturity Model Integration) models* are a collection of several maturity models and a

process evaluation method kept by the CMMI Institute [10], [11], [12].

The several components of the CMMI models are grouped in constellations, each one of which encompasses a specific interest area, such as Procurement (ACQ), Development (DEV) and Services (SVC).

The CMMI constellations were created in its version 1.2, which was published in 2006, when a new architecture was inserted in the models, allowing for the integration of the different processes contained in the CMMI models and with a larger focus on the improvement on the processes in the shared and the specific areas of each model.

A constellation is defined as a set of CMMI components that are used to build models, training materials and evaluation documents [10], [11], [12]. Among the CMMI constellations, the last one published was the Services one (CMMI-SVC), in 2009, which extended CMMI for development (CMMI-DEV) and CMMI for Purchase (CMMI-ACQ) for the practices that were necessary for organizations whose main business is to provide services.

Only the CMMI models have model constellations that aim to improve the processes, given that CMMI has spread the improvements that were concentrated into a single focus towards other focuses, as in the case of CMMI-ACQ and CMMI-SVC.

The components that are common to all CMMI models are called CMMI Model Foundation (CMF), and consist of the process areas that shared by all the models. On the other hand, the CMMI components that are included in two or more models are called Shared CMMI Material. Finally, the process areas that are specific for each models are given the mode name, showing that this area is unique to the model at hand [10], [11], [12]. Figure 2 shows the CMMI Model Constellation in its 1.3 version [30], with the number of process areas that exist in each model.

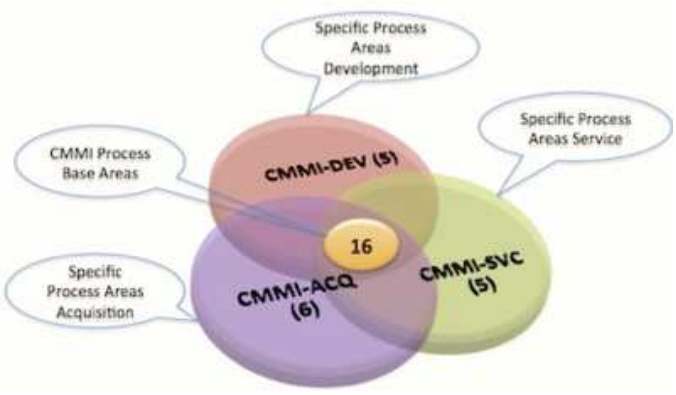


**Figure 2: CMMI Constellation [10], [11], [12].**

## III. Research Methodology

In this work we used a qualitative research methodology, a type that analyzes aspects of reality that cannot be quantified, focusing on the understanding, investigation and explanation of the dynamic of social relationships [17].

According to [18], qualitative research works with the universe of meanings, reasons, aspirations, beliefs, values and actions, which corresponds to a deeper relationship space of the processes and phenomena that cannot be reduced to operational variables [20], [22]. Hence, we did not use quantitative methodology for it would require data that is difficult to gather, evaluate and quantify.

There are several characteristics that can be attributed to qualitative research. Among them, we highlight, the transformation of phenomena into objective issues, a the creation of a hierarchy of actions to describe, understand and explain, a precise relationship between the global and the local in a phenomena, the observation of differences between the social and natural worlds, the respect to the interactive character between the goals sought by the researchers, its theoretical guidelines and its empirical data, the search for results that are as realistic as possible and the opposition to the defense of a single research model for all the sciences [19], [20], [22].

The research methodology used to perform this work is made of five phases, as presented in Figure 3.

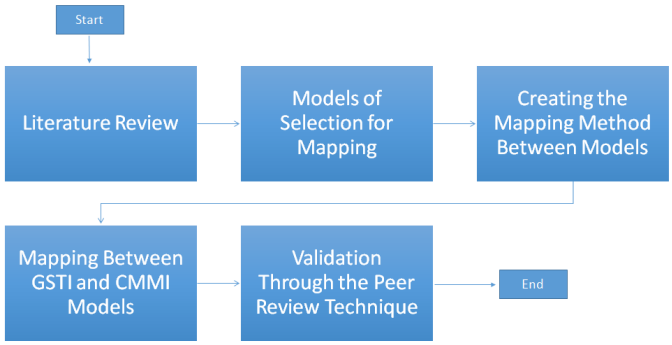


**Figure 3: Research Methodology Source: the authors (2016).**

The Literature Review phase intended to explore the technical literature in the field in order to understand the main topics connected to this research. Hence, we identified the topics and subjects of the research which were described throughout this work. Besides, during this phase, we researched the approaches, proposals and strategies that were used in every type of mapping. Due to the fact that this work was applied in the Brazilian scenario, we did not identify any similar work. Hence, we created our own method to capture the relationships between the GSTI processes and the specific practices of the CMMI models.

In the Mapping Models Selection phase, the goal was to identify which industry and business models could be used as a foundation to the mapping process. Hence, the CMMI models were used because they were the only ones with the constellation concept, that is, the one that defines specific practices for work areas such as Procurement (CMMI-ACQ), Development (CMMI-DEV) and Services (CMMI-SVC).

The Mapping Method Creation and in the Validation through Peer Review phases were detailed in the Research Execution Phases because during them there arose the need to structure systematically a method to map the models, here represented by the GCSTI and the CMMI in order to identify the relationships between them.

## IV. Research Execution

The phases for the creation of the mapping method were: (i) Study of the CMMI models and of the IT Solutions Procurement Guide; (ii) Definition of this work's scope; (iii) Definition of the classification criteria; (iv) Creation of the Initial Mapping Form; (v) Definition of the Standard Mapping Form; (vi) Definition of the Analysis Standard Form; (vii) Comparison between the GCSI and the CMMI models; (viii) Result Consolidation; and finally, (ix) Validation using Peer Review.

Figure 4 presents the phases for the creation of the Mapping Model. Each phase has a set of performed activities that will be described throughout this paper.

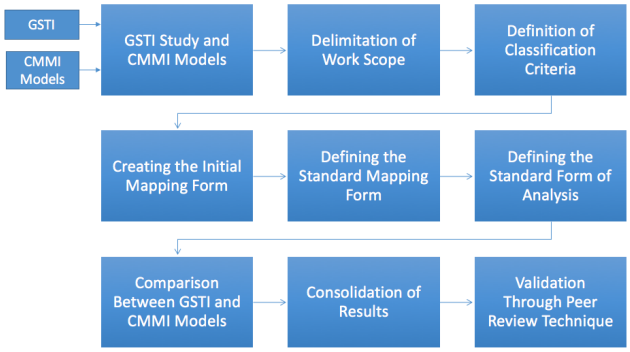


**Figure 4: Mapping Method between the GCSTI and the CMMI models. Source: Author (2016).**

In each mapping phase, we created artifacts to make it easier to understand and perform the activities. These artifacts will be described throughout this work.

A relevant aspect is that the main author of this research has experience and knowledge in the CMMI models, having participated in official Evaluations and Implementations of these models. Besides, the author participated in projects with the Brazilian Federal Government, in which the GCSTI and the IN/SLTI/MPOG 04/2014 were used as instruments to manage IT services providing contracts management.

The activities and the results of the mapping methods are described in details in the next sections.

### *A. Studies on the IT Solutions Procurement Guide and on the CMMI Models*

This section presents the phase in which we performed the studies on the CMMI Models and on the IT Solutions Procurement Guide (GCSTI) in order to perform the mapping. This phase intended to understand the structure of the CMMI models and of the GCSTI, analyze how they were built and how each one of them describe the required aspects, the processes, the activities and their artifacts.

This phase is essential to appropriately and adequately define the mapping. Both the CMMI Models and the GCSTI have their quirks, goals and different purposes. Hence, during this phase, we analyzed in details the aspects of each one of them, in order not to discard anything relevant a priori and to create the structure that is necessary for the next phases hitch depended on the results from this one.

Figure 5 presents the structures of the CMMI models and of the GCSTI that were discovered in this study phase.

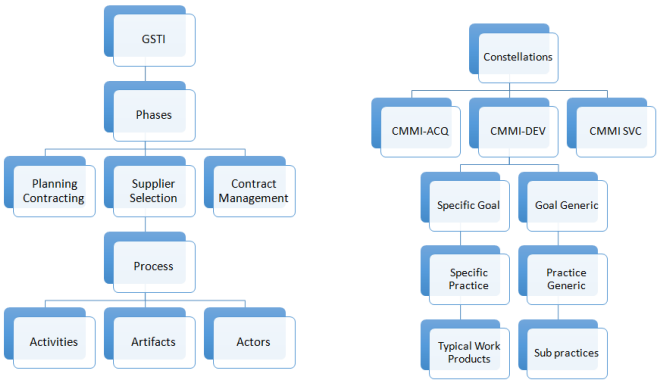


**Figure 5: A Study of the GCSTI and the CMMI models. Source: Author (2016).**

We performed the analysis of the CMMI models and the GCSTI after a series of studies in which w considered all the GCSTI processes and the CMMI models process areas up to maturity level 3. We imposed this limit because levels 4 and 5 of the CMMI deal specific with high maturity characterized with processes that are controlled statistically, which takes them out of the scope of this mapping.

GCSTI and CMMI models have different structures. While GCSTI is structured based on processes, based on the IT Solutions Procurement Process Phases, with activities, artifacts and mandatory roles, the CMMI models are structured into process areas, distributed into Maturity and Capacity Leves related to areas such as Project Management, Engineering, Support and Process Management. Hence, it would be necessary to understand the mapping dimension to represent it as appropriately as possible, with realistic results.

An important aspect identified in the CMMI models and GCSTI study phase is that the mapping must be structured based on requirements from one model towards the other. Hence, we selected GCSTI as the origin and the CMMI-ACQ, CMMI-DEV and CMMI-SVC models as the destination ones.

### *B. Definition of the Work Scope*

In this section we present de work scope definition phase in order to perform the mapping between the GCSTI and the CMMI models, as shown in Figure 6.

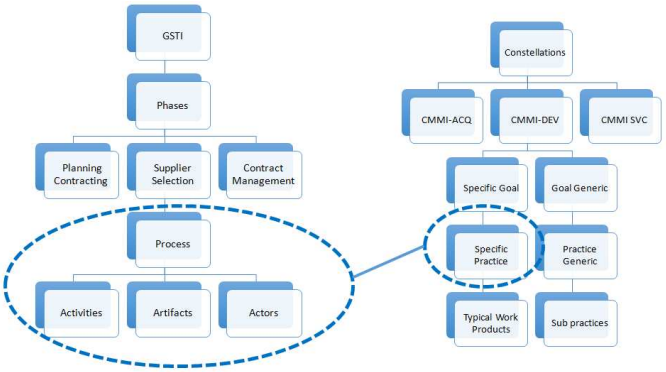


**Figure 6: Work Scope Delimitation. Source: Author (2016)**

In this phase, we considered the following aspects in order to structure the mapping between the models:

- The GCSTI, taking into consideration its phases, processes, activities and artifacts, compared with the specific practices of the CMMI-ACQ 1.3 model;
- The GCSTI, taking into consideration its phases, processes, activities and artifacts, compared with the specific practices of the CMMI-DEV 1.3 model;
- The GCSTI, taking into consideration its phases, processes, activities and artifacts, compared with the specific practices of the CMMI-SVC1.3 model, given that the depth of the processes allow us to better understand the relationship we were striving for with this mapping.

We excluded from the mapping structure the following items:

- Levels 4 and 5 of the CMMI models, because these levels deal with the performance of managed processes using Statistical Process Control (CEP);
- Generic Practices (GP) of each process area of the CMMI models, given that those practice determine the institutionalization of a defined process, that is, how much the process is present in projects, services of works in the organization.

We considered the following elements to support he mapping between the CMMI models and the GCSTI:

- The informative components of the CMMI models, among which exist the sub practices and the typical work products, because they offer implementation guidance for the specific practices of each process area;
- The specific and generic goals of each process area, given that those are evaluated directly when the specific and generic practices are fulfilled for each process area.

A point that must be observed is that while GCSTI defines "what must be done" and "how it must be done" for each process, activity and artifact, as foreseen in the IN/SLTI/MPOG 04/2014, the CMMI models do not define "how" one must perform each of its specific practices. The items are required by the model and they implementation "way" or "how" it should be done, is defined according to the way each organization approaches the work. Hence, we can also use the process defined in the GCSTI to implement the items required in the CMMI models, an approach that is taken in this mapping.

All the process areas of the CMMI models up to the Maturity Level 3 were considered to structure and perform the mapping. As mentioned in the previous section, the mapping and review of the processes were structured based on the GCSTI towards the CMMI models, that is, how much the processes in the GCSTI were related and/or present in the specific practices of the CMMI models, considering the specific classification criteria defined in the next section.

### *C. Definition of the Classification Criteria*

This section presents the classification criteria defined to perform the mapping between the GSCTI and the CMMI models. Based on the literature review performed, we identified the importance and the need for the definition of objective criteria for the classification of fulfillment of GCSTI process by the CMMI Models.

In this context, we structured a table with the classification criteria to support the mapping, so that the attribution was performed in a uniform way for each GCSTI process in comparison to the CMMI models, as shown in Table 1.

**Table 1 Classification criteria used in the mapping. Source: Author (2016)**

| Classification Criterion | | | Definition |
|---|---|---|---|
| **Acronym** | **Description** | **Attribution** | |
| ATD | Fulfills | 1 | The activities described in the GCSTI processes fulfill the specific practices of the process areas of the CMMI models and we attribute a value of 1. |
| ATDP | Fulfils partially | 0,5 | The activities described in the GCSTI processes partially fulfill the specific practices of the process areas of the CMMI models and we attribute a value of 0.5. |
| NADT | Does not Fulfill | 0 | The activities described in the GCSTI processes do not fulfill the specific practices of the process areas of the CMMI models and we attribute a value of 0. |
| NE | Does not exist | 0 | The activities described in the GCSTI processes do not exist in the process areas of the CMMI models and we attribute a value of 0. |

This classification is based on the SCAMPI method (*Standard CMMI Appraisal Method for Process Improvement*) [10], [11], [12], used in official evaluations made in the CMMI models. The attribution was transformed in 0, 0,5 and 1 in order to have an account of the Fulfills, Fulfills partially, Does not Fulfill and Does not Exist options.

After defining the classification criteria, we created forms to help the mapping process and the comparison between the

GCSTI processes and the CMMI models. We show these forms in the next section.

### *D. Creation of the Initial Mapping Form*

This section presents the forms used for the initial mapping between the GCSTI and the CMMI models. After the study phase and the definition of the classification criteria, a high level view was defined based on the results, taking into consideration our understanding of the GCSTI, the CMMI models and the classification criteria. used. The form allows us to group the phases of the GCSTI processes and the CMMI Models Process Areas in order to give direction to the understanding and allowing for the initially abstract description of those elements based only on one of them.

Table 2 presents the initial relationships we found in this work.

**Table 2 Initial Mapping Form. Source: Author (2016)**

| IT Solutions Procurement Guide (GCSTI) | Process areas from CMMI ACQ | Process areas from CMMI DEV | Process areas from CMMI SVC |
|---|---|---|---|
| **IT Solutions Procurement Planning Phase (PCTI)** | *<Inform the Process Areas for the CMMI ACQ connected to the IT Solutions Procurement Planning Phase>* | *< Inform the Process Areas for the CMMI DEV connected to the IT Solutions Procurement Planning Phase>* | *< Inform the Process Areas for the CMMI DVC connected to the IT Solutions Procurement Planning Phase >* |
| **IT Solutions Supplier Selection Phase (SFTI)** | *< Inform the Process Areas for the CMMI ACQ connected to the IT Solutions Supplier Selection Phase>* | *< Inform the Process Areas for the CMMI DEV connected to the IT Solutions Supplier Selection Phase>* | *< Inform the Process Areas for the CMMI SVC connected to the IT Solutions Supplier Selection Phase>* |
| **IT Solutions Contract Management Phase (GCTI)** | *< Inform the Process Areas for the CMMI ACQ connected to the IT Solutions Contract Management Phase>* | *< Inform the Process Areas for the CMMI DEV connected to the IT Solutions Contract Management Phase>* | *< Inform the Process Areas for the CMMI SVC connected to the IT Solutions Contract Management Phase>* |

After defining the form for the initial mapping from the GCSTI to the CMMI models, we formed an initial high level view of their relationship. Hence, we created a standard form showing the details of the structure of both models, allowing us to perform the mapping systematically based on the defined criteria. The standard mapping form will be detailed in the next section.

### *E. Definition of the Mapping Form*

This section presents the forms we define to help perform the mapping. The first form was created in order to list the important information in the GCSTI that would be used to perform the mapping.

The GCSTI was examined and the information that represent its structure which will be listed for the initial mapping model are: GCSTI phases; GCSTI processes; GCSTI activities; and Artifacts. This information represents the four depth and detail levels of the elements that are essential to perform the GCSTI mapping. It is important to highlight that the terminology of the mapping is not equal to the maturity levels adopted by the CMMI models. The goal at this time is to identify the depth of the study, review and analysis of the GCSTI processes and the CMMI models in order to map them adequately at a second moment.

Figure 7 presents the GCSTI detail levels that were the target of this research.

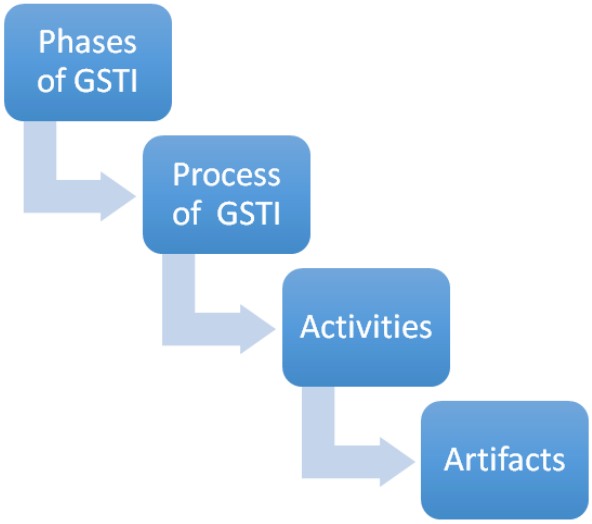


**Figure 7: GCSTI detail levels. Source: Author (2016)**

Next, we present the first form that was created with the information that represent the GCSTI detail levels, as shown in Table 3.

| GCSTI Phases | GCSCTI Processes | GCSTI Activities | Artifacts |
|---|---|---|---|
| *<Acronym of the GCSTI phase that corresponds to the listed process and activity>* | *< Acronym of the GCSTI process that corresponds to the listed process and activity >* | *<description of the activity that corresponds to the GCSTI phase and process >* | *<Description of the artifact created/ assembled in the GCSTI process activity>* |
| **Level 1 (N1)** | **Level 2 (N2)** | **Level 3 (N3)** | **Level 4(N4)** |

The second form was created with the same goal of the first one, that is, list the relevant information. The difference is that the second form lists the information on the CMMI models which will be used to perform this mapping.

The CMMI-ACQ, CMMI-DEV and CMMI-SVC models were studied and the information that represent the models structure necessary for the initial mapping model are: CMMI constellation; maturity level; Process Area; Gal; Specific Practice and Sub Practice. This information represents the 7 depth levels and the essential detail elements to perform the mapping between GCSTI and the CMMI Models, as shown in Figure 8.

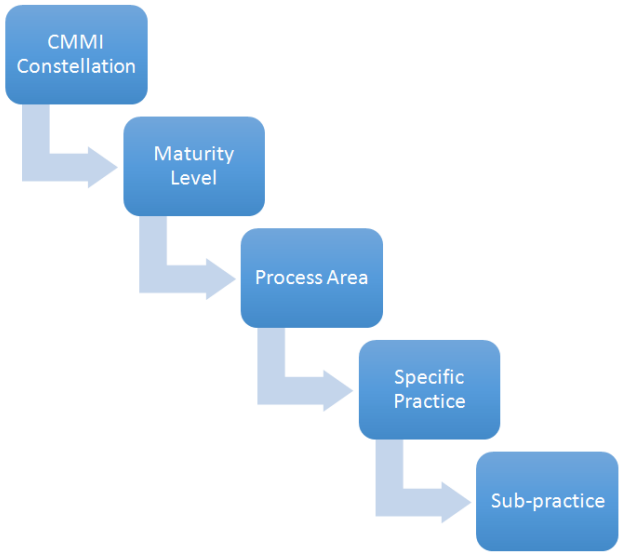


**Figure 8. CMMI Detail Levels. Source Author (2016)**

Next, we created the second form containing the information that represent the detail level of the CMMI models, as shown in Table 4.

After gathering this information in the forms described in sections E and F, they were used to start the analysis activity, with the goal of identifying if the GCSTI processes complied with the specific practices from the CMMI models.

The next section will show the forms used to perform the mapping.

| CMMI Constellation | Maturity Level | Process Area | Goal | Specific Practice | Sub Practice |
|---|---|---|---|---|---|
| *<Acronym of the CMMI Constellation identified and listed>* | *<Description of the maturity level related to the process area>* | *<Acronym of the CMMI process area identified and listed>* | *<Description of the goal of the CMMI process area identified with the item required in the process area>* | *<Acronym of the specific CMMI practice identified and listed with the expected result of the specific practice>* | *<Description of the content of the sub practice related to the specific CMMI practice>* |
| **Level 1 (N1)** | **Level 2 (N2)** | **Level 3 (N3)** | **Level 4 (N4)** | **Level 5 (N5)** | **Level 6 (N6)** |

*F. Definition of the Standard Analysis Form*

This section presents the standard form used to perform the detailed comparison between the GCSTI and the CMMI models. After finishing the phase defined in Section E, we realized that we needed a new form considering the elements mapped in forms 3 and 4, with the goal of analysis in detail the information in each table.

The information that represent the mapping structure was selected fo the detailed comparison form, including a filed called "Grade" for classification assignment. Besides, the detail levels of the GCSTI and the CMMI models were kept, but we decided for 4 levels of detail for the CMMI models, in order for the analysis to be performed according to the SCAMPI method, considering the fulfillment of specific practices and goals of each process area.

Figure 9 presents the element selection for the creation of the analysis form.

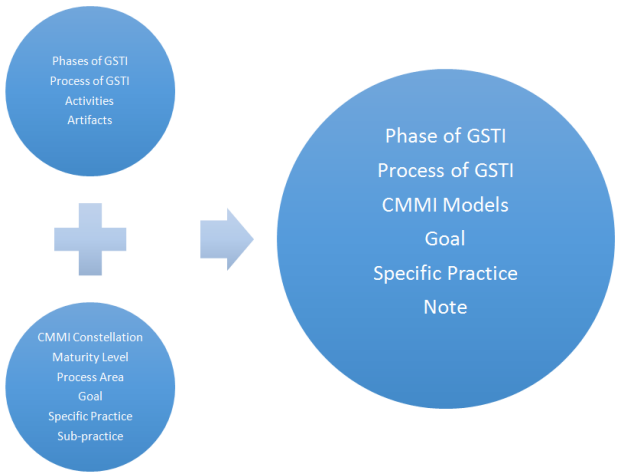


**Figure 9: Element selection for the comparison. Source: Author (2016)**

The standard comparison form model is presented in Table 5.

**Table 5 Analysis to GCSTI and CMMI Models. Fonte: Author (2016)**

| GCSTI Phase | GCSTI Process | GCSTI Activity | CMMI Model | Process Area | Goal | Specific Practice | Grade |
|---|---|---|---|---|---|---|---|
| *<Acronym of the GCSTI phase that corresponds to the process and activity >* | *Acronym of the GCSTI process that corresponds to the process and activity >* | *Acronym of the GCSTI activity that corresponds to the process and activity >* | *<Acronym of the related CMMI constelation>* | *<Acronym of the related CMMI Process area >* | *<Description of the goal related to the CMMI process area identified with the required item in the process area>* | *<Acronym of the specific CMMI practice related >* | *<Grade assigned considering the comparison between the GCSTI elements and the CMMI models >* |
| **Level 1 (N1)** | **Level 2 (N2)** | **Level 3 (N3)** | **Level 1 (N1)** | **Level 2 (N2)** | **Level 3 (N3)** | **Level 4 (N4)** | |

Besides defining the classification criteria used for the mapping, a new calculation was defined to help calculate the average of the values that would be transformed into a coverage and compliance percentage (%) by the GCSTI of the specific practices of the CMMI models. For that, the forms were prepared so that the calculation was made automatically, considering the number of specific practices that were fulfilled and the total was divided by the number of practices existing in each Process Area of the CMMI models.

The form was created to demonstrate the coverage degree of each specific practice of the CMMI models by the GCSTI processes as presented in Table 6.

After the table was created, we made some adjustments to improve the classification, assignment and afterwards, result analysis.

Given that the GCSTI describes defined processes, the mapping analysis structure was performed taking into consideration the process areas of the CMMI models maturity level 3. This choice was made because the maturity level 3 is characterized as the "Defined" level and contains specific practices that contain required process items defined for all the process areas. Hence, for each process area from CMMI-ACQ, CMMI-DEV and CMMI-SVC, we created a table with the results from the MAPPING between the GCSTI and the CMMI models.

### *G.Comparison between GCSTI and the CMMI models*

This section will present the comparison between the GCSTI and the CMMI models, done after filing the forms previously described.

These forms are not made available online, given that they contain some information that is protect by a confidentiality agreement.

Based on the results found, it is possible to perform a comparison and an analysis, and discover which are the coverage results of the CMMI models based on the GCSTI.

In the next step, we will consolidate the mapping results and the comparison between the GCSTI and the mapping models.

**Table 6: Classification of the coverage degree for each process. Source: The Author (2016)**

| **CMMI Constellation** *<Inform which is the adopted CMMI model>* | | | | | |
|---|---|---|---|---|---|
| **Process Area** | **Goal** | **Specific Practice** | **Classification** | **Frequency** | **Evidence** |
| *<Acronym of the related CMMI process area >* | *<Description of the goal of the CMMI model process area>* | *<Acronym of the related CMMI specific practice >* | *<If fulfills, assign "1", if partially fulfills, assign "0,5" for either "does not fulfill" or "does not exist", assign "0"">.* | *<Number of times the specific practice is found in the GCSTI processes >* | *<Describes the evidence found in the GCSTI which fulfills the CMMI models >* |
| **Total** | | | *<Average of the assigned values assigned for the process area practices >* | | |
| **Level 2 (N2)** | **Level 3 (N2)** | **Level 4 (N2)** | | | |

### *H.Results Consolidation*

This section presents the final consolidated results from the mapping performed.

Some important results were identified when we performed the final consolidation of the mapping. The common or core areas and the shared areas of the CMMI models achieved the same coverage percentage by the GCSTI processes which, due to their similarity, had not their results changed.

At the Maturity Level 2, the following process areas achieved 100% coverage: Project Planning (PP); Work Planning (WP); Project Management and Control (PMC); Work Management and Control (WMC) and Product Process Quality Assurance (PPQA). This means that 100% of the specific practices of those areas were fulfilled by activities and processes of the GCSTI model. The other process areas achieve similar coverage percentages: Configuration Management (CM), 85,71%, Requirements Management (REQM), 80%, Measurement and Analysis (M&A), 68,75%.

The Configuration Management (CM) process area was not fully covered due to the lack of identification of all configuration items that make the configuration and management system, which makes it difficult to manage the changes of all elements that comprise the contract management. Besides, the creation of contract baselines is not defined, existing only the definition of deliverables

The Requirement Management (REQM) process area was not fulfilled because of the lack of requirement traceability, which makes it difficult to analyze the impact in requirements changes.

Finally, the Measurement and Analysis (M&A) area achieved the lowest percentage coverage, has flaws related to the specification of measurements for indicators monitoring. Besides, the GCSTI model does not define indicators gathering, storage and analysis procedures, what may compromise the measurement system.

At the Maturity Level 3, the Process Area of Decision Analysis and Resolution (DAR) was completely (100%) covered. The others achieve different coverage results, including the following: Risk Management (RSKM), 85,71%, Integrated Project Management (IPM) and Integrated Work Management (IWM), 70%; Organizational Process Definition (OPD), 50%; Organizational Training (OT), 28,57%; Organizational Process Focus (OPF), 11,11%.

The Risk Management Area (RSKM) was not totally covered because of the lack of specification of risks sources and categories, making it more difficult to identify risks in contracts.

The Integrated Project Management (IPM) and Integrated Work Management (IWM) has flaws concerning the definition of processes that give an orientation to the contribution with the organizational assets, causing the loss of knowledge learned from the experiences and lessons learned during the procurement process.

The Organizational Process Definition (OPD) area has flaws in some points such as: lack of description of life cycle models that can guide the organization in the procurement process; lack of definition of an organizational measurement repository which can store all the organization indicators; and lack of definition of norms for the definition of work environment and team formation in the context of the organization.

The Organizational Training (OT) area does not define the strategic training needs and which are the trainings that are under the responsibility of the organization. Besides, there are no training records, which makes it impossible to evaluate their efficacy, what compromises the management of the organization training area.

Finally, the Organizational Process Focus (OPF) area has several problems in the definition of process needs, in the identification of improvements, in the establishment and monitoring of processes, as well as in the incorporation of lessons learned in the processes.

Based on these results, we can see that there is a deficiency in the execution sequence in the GCSTI processes in comparison to the CMMI models. Considering that the GCSTI covers many process areas from the CMMI models in different maturity levels. At the same time in which process areas related to Procurement, Development and Services (areas from the maturity level 3) are covered almost entirely, some areas from the maturity level 2 that defines the managed level are not completely covered. Hence, the areas related to the maturity level 3 are not being executed after the coverage of the maturity level 2, which can result in problems and difficulties in project execution.

After finalizing this mapping and model comparison phase, we identified the need to represent the results graphically, to improve the presentation and facilitate the final visualization of the mapping results. Hence, we build graphics to demonstrate these results and the coverage percentage of each CMMI model process area in relation to the GCSTI process.

The graphics structure was built in the same way to present the result for each CMMI model, varying only the process areas that are specific for each model.

The graphics present a final view of the coverage percentage for the CMMI models process area by the GCSTI processes.

The mapping results for the specific areas for each CMMI model will be detailed in the next subsections.

### *1) Consolidation results on the CMMI-ACQ model*

Specifically concerning the CMMI-ACQ model, the process areas achieved a large coverage percentage by the GCSTI processes and activities, indicating that the latter fulfills the requirement of the specific practices of the CMMI-ACQ model.

Figure 9 shows the result of the mapping between these two models, depicting the existing adherence according to the mapping performed.

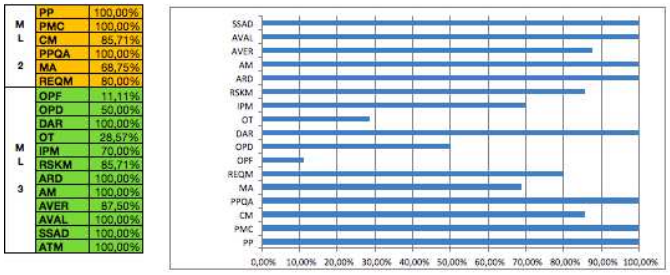


**Figure 9. Adherence to the CMMI-ACQ model by the GCSTI. Source: Author (2016).**

Several areas were fully (100%) covered: Acquisition Requirements Development (ARD), Acquisition Management (AM); Acquisition Validation (AVAL); Supplier Solicitation and Development Agreement (SSDA) and Acquisition Technical Management(ATM), demonstrating the strong relationship between the activities defined in the GCSTI and the implementation of the process areas of the CMMI-ACQ model.

The Acquisition Verification (AVER) process was only 87,5% covered because this area does not define a peer review method as a way to verify artifacts from the acquisition process.

Analyzing these results and the Brazilian software industry, we realize that in order to comply with the GCSTI, the companies that serve the government must have defined processes related to the acquisition of products and services,

demonstrating some level of maturity and capacity in their processes. Nevertheless, the companies are not ready to comply with the GCSTI demands, given that those companies do not have the defined processes that contemplate the acquisition areas.

*2) Consolidation results on the CMMI-DEV Model*

There are many process areas from the CMMI-DEV models which achieved a high percentage of coverage, just like the CMMI-ACQ, indicating that these activities and processes adhere to the specific practices of the CMMI-DEV model.

Figure 10 presents the results of the mapping from the GCSTI and the CMMI DEV model, showing the adherence existing between the models.

Several areas were fully (100%) covered: Requirement Development (RD); Technical Solution (TS); Product Integration (PI) and Validation (VAL), showing the strong relation between the activities defined in the GCSTI and the process areas from the CMMI-DEV model.

The Verification (VER) process area achieve 87,5% coverage because, just like in the Acquisition Verification from CMMI-ACQ, it is not defined a peer review method as a way to verify artifacts.

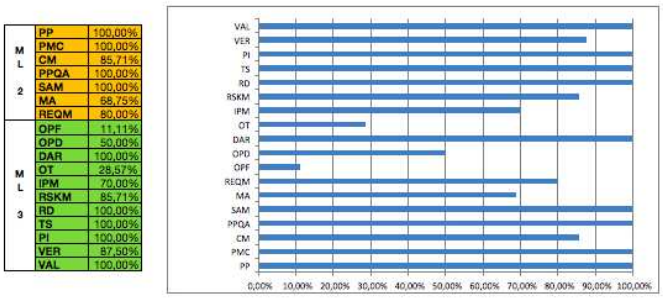


**Figure 10. Adherence to the CMMI-DEV model by the GCSTI. Source: Author (2016).**

The software engineering process areas contain the key elements for an efficient software process, encompassing all the production cycle, from the conception to the delivery of the software and its maintenance. These areas are at the CMMI-DEV maturity level 3 and represent yet an evolutionary path for the organization in search of a mature and disciplined process.

Analyzing these results and the Brazilian software industry, we can see that in order to comply with the GCSTI the IT solution providers must have defined processes in the area of software development and maintenance, showing some level of maturity and capacity in its processes. Considering the maturity of the national software industry, we can see that the companies are not able to comply with the GCSI, given that those companies do not have process maturity tat contemplate all areas of software development and maintenance.

*3) Consolidation results on the CMMI-SVC Model*

There are many process areas from the CMMI-SVC models which achieved a high percentage of coverage from the GCSTI activities, indicating that these activities and processes adhere to the specific practices of the CMMI-DEV model.

Figure 11 presents the results of the mapping from the GCSTI and the CMMI SVC model, showing the adherence existing between the models.

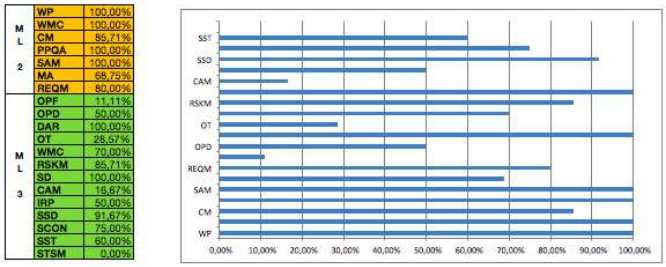


**Figure 11. Adherence to the CMMI-SVC model by the GCSTI. Source: Author (2016).**

The mapping to the CMMI-SVC model found two different results which are both significant.

At the maturity level 2, the Service Delivery (SD) area was 100% covered by the processes and activities from the GCSTI.

At the maturity level 3, no process are from the CMMI-SVC achieved 100% coverage and compliance. The other areas had different compliance levels: Service Systems Development (SSD), 91,67%; Service Continuity (SCON), 75%; Service System Transition (SST), 60%, Incident Resolution and Prevention (IRP), 50%; Service Management Strategy (STSM), 50%; and Capacity and Availability Management (CAM), with 16,67% coverage and compliance.

The nucleus of the service engineering, that is, the areas that define processes to establish, deliver and manage service, are partially covered by the GCSTI, which demonstrates a deficiency in the service system, given that not all the areas that comprise this system were fully covered. These areas represent the service system engineering at the CMMI-SVC model maturity level 3, containing processes defined for all the activities related to service providing.

The Service System Development (SSD) area does not define a peer review method as a way to verify artifacts.

The Service Continuity (SCON) area does not have identification and prioritizing of functions and resources that are essential to the service system. Hence, without the identification of those elements, it is not possible to plan the service continuity effectively.

The Service System Transition (SST) area does not establish a preparation mechanism for the services changes and transitions. Hence, it does not establish a way to evaluate and control the impacts of the service transition.

The Incident Resolution and Prevention (IRP) area does not establish an approach to prevent and solve incidents, as well as

it does not define a system to manage incidents. Besides, it does not perform the selection and analysis of incidents for which there are no solution, so that their future repetition can be avoided.

The Service Management Strategy (STSM) does not establish a standard service plan.

Finally, the Availability Capacity Management (CAM) are does not define: (i) measurement selection; (ii) service system representation, (iii) capacity and availability monitoring, as well as the reports with the service results. These results have a reflex on the service system, given that the lack of implementation of those parameters makes it impossible to manage the services' availability and capacity.

Analyzing these results and the Brazilian software industry, we can see that in order to comply with the GCSTI, the IT services support, operation development and execution companies must have defined processes for all the service providing activities that involve strategy, capacity, availability, continuity, delivery and transition of services. They must also have some accident prevention and some maturity and capacity levels in their services.

Considering the maturity of the national software industry, we can see that the companies are not able to comply with the GCSI, given that those companies do not have process maturity that contemplate the daily working and operation of a service system.

### *I. Validation through Peer Review*

The peer review was performed in two parts. The first one was made with a group of 5 experts. Based on the consensus among the reviewers, we performed some adjustments, creating the first revised version of the mapping.

Table 7 presents the form used in the peer review.

**Table 7: Peer Review. Source: The Author (2016)**

| **Peer Review of the Mapping between GCSTI and the CMMI Models** | |
|---|---|
| **Reviewers Profile**<br>**Reviewer 1:** (X) Government Experience; (X) Industry Experience; (X) Academic Experience; Other: _____.<br>**Reviewer 2:** Government Experience; (X) Industry Experience; (X) Academic Experience; Other: _____.<br>**Reviewer 3:** (X) Government Experience; (X) Industry Experience; Academic Experience; Other: _____.<br>**Reviewer 4:** Government Experience; (X) Industry Experience; Academic Experience; Other: _____.<br>**Reviewer 5:** Government Experience; Industry Experience; (X) Academic Experience; Other: _____. | |
| **CMMI Model:** | |
| **Maturity Level:** | |
| **Process Area:** | |
| **Adopter Classification:** | 1 - No problem - SP<br>2 - Severe Technical Problem - PTA<br>3 - Small Technical Problem - PTB<br>4 - Observation/Improvement - OM<br>5 - Does not apply – NA |
| **SG _____** | |
| **Corrections:** | |

The first phase of the peer review was performed to support the result consolidation and suggest improvements in the mappings based on the consensus and on the adjustments made by the reviewers, as presented in Table 8.

**Table 8: Improvement suggestions in the first phase of this mapping. Source: The author (2016)**

| CMMI Model | Number of SG's | % of improvement in the first phase of the review |
|---|---|---|
| **CMMI-ACQ** | 37 | 13% |
| **CMMI-DEV** | 41 | 7% |
| **CMMI-SVC** | 45 | 20% |

In order to guarantee more robust and cohesive results, the new mapping version was submitted to a second round or peer review, which include the author of this work and a reviewer who is a leader and an official CMMI instructor.

This new review step resoled in some changes to contribute to the final result consolidation, as presented in Table 9.

**Table 8: Improvement suggestions in the second phase of this mapping. Source: The author (2016)**

| CMMI Model | Number of SG's | % of improvement in the second phase of the review |
|---|---|---|
| **CMMI-ACQ** | 37 | 5% |
| **CMMI-DEV** | 41 | 5% |
| **CMMI-SVC** | 45 | 15% |

The consolidation of the changes performed in both phases of the peer review considered the number of changes in the goals (SG's) in the process areas of each CMMI model.

Observing the validation results found in the peer review, we can see that both phases of the review resulted in changes in the mapping. In the first phase of the peer review (the one performed by the expert's panel), the percent of change was different for all CMMI models. The CMMI-SVC was the one with the higher percentage (20%) of change. The CMMI-DEV, on the other hand, was the one that required the smaller amount of change (7%).

In the second phase of peer review, including an evaluator leader in the CMMI models, the CMMI-SVC was the one with the highest percent of change, 15%. The other two models, CMMI-CQ and CMMI-DEV had the same percent of changes (5%).

The review results were performed in two phases because of the qualification of the involved professionals. Even though there was no formal third review phase, the changed results from the second phase were reviewed by all the involved in both phases and all of them agree with the final results.

## V. Conclusion

This work presented a mapping between the GCSTI from

the APF and the CMMI-ACQ, CMMI-DEV and CMMI-SVC models, with the goal of identifying and analyzing the maturity and the adherence of the GCSTI processes to the CMMI models. The mapping was performed according to the presented research methodology.

The research results allowed us to identify the maturity and the adherence of the GCSTI to the CMMI models.

In general, the GCSTI processes are equivalent to the CMMI models in the maturity level 3, given that all activities demanded in the GCSTI are described in the maturity level 3 of the CMMI models, characterizing an organization with a "defined process", that is, an organization that has a process definition for all areas.

The process execution at the CMMI model maturity level 3 demands organizational maturity and capacity for process improvement in a controlled way. Hence, if there is an equivalence between there GCSTI processes and the process areas from he CMMI models maturity level 3, we can come to the conclusion that the GCSTI demands maturity and capacity of processes at that level.

Considering that the Brazilian technological market is made of 94% of micro or small software companies and these companies to do have maturity in their processes and depend on the government to survive, we can say that there is a "roadblock" in the process between the supplier and client, given that the GCSTI demands are above the companies productive capacity.

Based on the results from this result, we can come to the conclusion that there is a deficiency in the definition of maturity of the GCSTI, given that this complies with several process areas from the CMMI models in different maturity levels and there is not an execution sequence of the processes alignment with the development of projects, products and services.

The GCSTI processes demand maturity during their execution. Nevertheless, this guide does not define maturity on its structure. Considering the Brazilian software and services industry, the execution of GCSTI processes may show difficulties, given that it demands high maturity from the service providing companies, being inadequate for the context in which the Brazilian companies are in.

### *A. Contributions from this research*

The main contributions from this research are the following:

- The bibliographic review specific for this area, including the IT Solutions Procurement Model and the Normative Instruction MP/SLTI 04/2010;
- The mapping model from the GCSTI to the CMMI Models;
- The execution of the mapping from the GCSTI to the CMMI models, including the CMMI-ACQ, CMMI-DEV and CMMI-SVC models, taking into consideration the processes, activities and artifacts from the GCSTI and the specific practices from the CMMI models;
- The perception of maturity and adherence of the GCSTI in relation to the CMMI models.

### *B. Difficulties and Limitations of this Study*

We identified some difficulties when performing this work; Among them, we highlight the following:

- The lack of works on the IT Solutions Procurement Guide;
- The lack of works related to the experience of IT service providers;
- The lack of access to information from departments of the Federal Government;
- The difficulty to propose solutions that demand activities involving departments of the Federal Government.

This work has the following limitations:

- The fact that the mapping was performed based only on the GCSTI process definitions, given that it was not possible to perform the mapping based on the executed contracts, since the characteristics of each contract are specific and individual, besides being of limited access;
- The result validation was performed based on expert evaluation, considering the nature of the research.

### *C. Future Work*

As future work, we intend to:

- Change the mapping model and perform it representing the fulfillment degree to the GCSTI, including the fulfillment degree for each step of the hiring process;
- Review the classification criteria used to perform the mapping in order to evaluate the need to include new criteria that allow us to better identify the fulfillment and coverage between models;
- Evaluate the mapping based on contract execution, considering the hiring results;
- Based on the mapping results, write a guide with the best practices for IT solutions procurement, considering the knowledge areas evolved in the hiring process.

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