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Multi-model Software Process Improvement based on C2M and MR-MPS-SW Models

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ARTICLE INFO	ABSTRACT
Published: 8 Sep. 2020	The pursuit of competitive advantage has boosted organizations to improve their development processes. With this, a range of maturity models for software development processes has emerged on the market. In this sense, research efforts have been increasingly necessary to understand how organizations should deal with the various maturity models, given the heterogeneity of the characteristics of these models. In this context, this work aims to propose a mapping between MR-MPS-SW and C2M models. The proposed mapping was reviewed and evaluated by five experts with experience in software process improvement. This mapping allowed us to identify that 82.2% of C2M practices with some type of coverage for the expected MR-MPS-SW results. Finally, it is possible to see that the models here mapped are not conflicting, but rather complementary, with C2M being partially adherent to MR-MPS-SW.

INTRODUCTION

The spread of globalization followed by the competition on the world market has boosted organizations for continuous innovations and improvements for processes and products (BALDASSARRE et al., 2010). In this respect, Mirna et al. (2011) present the software process improvement as the most critical and important effort that any organization must target, regardless of having its team organized in a traditional or distributed way, to improve its software development process capacity.

Despite the wide range of improvement models, many companies tend to adopt more than one of them, because not always a simple model can completely accomplish their requirements (GARCIA et al., 2016). Still, according to Garcia et al. (2016), the major difficulty in implementing more than one model is that each one has a different type of structure, generating conflicts and misunderstandings concerning what will be implemented in the enterprise.

Among the process improvement models found in the market, it is worth highlighting the MR-MPS-SW (Software Reference Model) (SOFTEX, 2016b) and the C2M (Communication Maturity Model) (FARIAS JUNIOR, 2014). MR-MPS-SW is one of the models that make up the MPS.BR Program, defined by SOFTEX (2016b) as a long-term mobilizing program, which aims to increase the organization's competitiveness by improving its processes. On its turn, C2M appears as an emerging maturity model focused on communication. C2M was proposed aiming to improve the communication of distributed software development teams. This model was built based in the literature and empirical data and inspired by other maturity models, like CMMI-DEV, MR-MPS-SW, eSCM and Wave (LEITÃO JUNIOR et al., 2017; FARIAS JUNIOR et al., 2016).

MR-MPS-SW and C2M have distinct characteristics and objectives, however, companies may want the process improvement provided by MR-MPS-SW and, at the same time, seek for the communication improvement proposed by C2M. In this sense, the heterogeneous characteristics of the models require more research about dealing with many process models at a time (SAHIBUDDIN et al., 2018).

In light of this context, the research question guiding this work is: What is the C2M adherence level with MR-MPS-SW? Grounded in this problem, the main aim of this work is to present a mapping among the MR-MPS-SW and C2M maturity models. This paper presents in an extended way the results discussed in Vieira (2020).

According to Baldassarre et al. (2010), when companies decide to adopt multi-model improvement initiatives, they must be prepared to the challenges, taking advantage of the best practices in the best way possible. This study can support organizations

wishing to implement the maturity models mapped here. One of the major benefits of constructing mappings among models is that they supply concrete and traceable information for origin approaches and can serve as a basis for multi-model evaluations (KELEMEN, 2013).

In addition to this Section, this paper is organized into other 6 Sections. In Section 2, the main concepts related to multi-model processes are presented. Section 3 describes the MR-MPS-SW and C2M models. Section 4 describes the methodology used to construct the mapping. The mapping and pair review results are presented in Sections 5 and 6. Section 7 presents the main limitations and threats to the results of this research. Finally, Section 8 presents the concluding remarks.

IMPROVEMENT OF MULTI-MODEL PROCESSES

Organizations invest in process improvement aiming to reach higher quality in their products, in addition to obtaining qualifications required for public and international bidding (ARAUJO et al., 2015). Still, according to Araujo et al. (2015), although there are several process improvement models, to believe in any model defined thus far as a complete solution for process management in the IT context would be unwise.

According to Pardo et al. (2012), some factors can influence the use of multiple models, such as market niches for specific models, improvement of practices from legacy processes, business positioning, leverages or incorporation, process capacity improvement and business growth. The use of multi-model environments demands extensive knowledge about these models and their intersections so that the joint implementation does not generate redundant processes, as well as unnecessary efforts and costs (ARAUJO et al., 2015). For Mirna et al. (2011), maturity models are not mutually exclusive, even when offering exclusive features and addressing specific issues.

Organizations want to benefit from advantages from different models and representations (PELDZIUS; RAGAISIS, 2011), however, according to (Kelemen 2013), the simultaneous use of multiple approaches can bring problems, such as the identification and manipulation of different approaches with different structures, granularity, terminology, contents, size, and complexity. Organizations must fight against the complexity and difficulty of understanding and interpreting various models at the same time (PARDO et al., 2012).

As an effort to support organizations in the selection of a correct implementation of the improvements, the multi-model environments arise allowing to use the best practices from different reference models (MEIJA et al., 2016). To Araujo et al. (2015), efforts must be done to identify intersections and common parts between the models, creating a multi-model improvement solution.

Multi-model initiatives can be classified in Kelemen (2013): mapping, integration, and harmonization. Harmonization happens when characteristics from approaches with independent quality are aligned with each other (such characteristics can be, for example, structure or terminology). A multi-model initiative is called integration when, instead of having autonomous quality approaches, the approaches are unified in an "integrated" approach. Finally, the multi-model initiative is called mapping when specific parts from different quality approaches, like requirements or terminologies, are compared.

From the categorization of multi-model initiatives presented by Kelemen (2013), this research can be characterized as a mapping, since it concentrates on identifying and mapping requirements from two different quality approaches (C2M e MR-MPS-SW).

Concerning the mapping of two or more models, many works have been done in this direction. Araujo et al. (2015) map MR-MPS-SW with CERTICS. Peldzius and Ragaisis (2011) map CMMI-DEV with ISO/IEC 15504. Mello (2011) presents a mapping of the models MPS and CMMI-DEV. Garcia et al. (2016) maps CERTICS and CMMI-DEV. SOFTEX published, yet, three other mappings, from MR-MPS-SW to NBR ISO/IEC 29110-4-1:2012 (SOFTEX, 2012a), from MR-MPS-SW to MoProSoft (SOFTEX, 2012b) model and from MR-MPS-SW to CMMI-DEV v1.3 (SOFTEX, 2016).

MR-MPS-SW AND C2M REFERENCE MODELS

The Brazilian Software Process Improvement Program (Programa de Melhoria de Processo do Software Brasileiro - MPS.BR) aims at improving the software processes in Brazilian companies from all regions, at an affordable cost, focused mainly at micro, small and medium-sized enterprises. Rules are established for its implementation and evaluation, giving support and ensuring that MPS.BR is being applied consistently with its definitions (SOFTEX, 2016b). The MPS model is described following a guide format, composed of General Guide (MR-MPS-SW), Implementation Guides, Evaluation Guides and Acquisition Guide.

The General Guide has a general and detailed description of the Reference Model (MR-MPS-SW), its components and the common definitions necessary for its understanding and application. The Implementation Guide describes how to implement a given level of the MR-MPS-SW model. The Evaluation Guide reports the process and the MA-MPS evaluation method, the requirements for leader and adjunct assessors and assessment institutions. The Acquisition Guide describes the process of software acquisition and correlated services (SOFTEX, 2016b).

The MR-MPS-SW reference model defines 7 maturity levels, where each level characterizes the stage where the organization lies about its maturity process in software development, as shown in **Table 1**. These maturity levels are a combination of the process and its capacity (ARAUJO et al., 2015). Processes are described in MR-MPS-SW in terms of purpose and expected results.

Table 1. MR-MPS-SW components. Source: SOFTEX (2016b)

Level	Processes	Process Attributes
A		AP 1.1, AP 2.1, AP 2.2, AP 3.1, AP 3.2, AP 4.1, AP 4.2 , AP 5.1 and AP 5.2
B	Project Management (GPR) - Evolution	AP 1.1, AP 2.1, AP 2.2, AP 3.1 e AP 3.2, AP 4.1 and AP 4.2
C	Risk Management (GRI)	AP 1.1, AP 2.1, AP 2.2, AP 3.1 and AP 3.2
	Development for Reutilization (DRU)	
	Decision Management (GDE)	
D	Verification (VER)	AP 1.1, AP 2.1, AP 2.2, AP 3.1 and AP 3.2
	Validation (VAL)	
	Project and Product Construction (PCP)	
	Product Integration (ITP)	
	Requirements Development (DRE)	
E	Project Management (GPR)- Evolution	AP 1.1, AP 2.1, AP 2.2, AP 3.1 and AP 3.2
	Reutilization Management (GRU)	
	Human Resources Management (GRH)	
	Organizational Processes Definition (DFP)	
	Organizational Process Assessment and Improvement (AMP)	
F	Measurement (MED)	AP 1.1, AP 2.1 and AP 2.2
	Quality Assurance (GQA)	
	Project Portfolio Management (GPP)	
	Configuration Management (GCO)	
	Acquisition (AQU)	
G	Requirement Management (GRE)	AP 1.1 and AP 2.1
	Project Management (GPR)	

Table 2. C2M components. Source: Farias Junior (2014)

Maturity Area	Maturity Factor	Maturity Level	Practices
People	Cultural Differences Management	2 and 3	CD1, CD2, CD3, CD4 and CD5
	Trust Development	3	TDE1, TDE2 and TDE3
Project	Communication Support Tools	2 and 3	TC1, TC2 and TC3
	IT Infrastructure	2 and 3	INF1, INF2 and INF3
	Geographic Distance Management	2 and 3	GD1, GD2, GD3 and GD4
	Temporal Distance Management	2 e 3	TD1, TD2, TD3 and TD4
	Stakeholder Management	2, 3 and 4	SM1, SM2 and SM3
	Monitoring, Measurement and Analysis	4	MA1, MA2 and MA3
	Communication Planning	2 and 3	CP1, CP2, CP3, CP4, CP5, CP6, CP7, CP8 and CP9
	Organizational	4	CC1, CC2, CC3 and CC4
	Risk Management	2 and 3	RM1, RM2, RM3 and RM4
	Communication Standards and Policies	2 and 3	PP1 and PP2
	Communication Training	3 and 4	CT1, CT2, CT3 and CT4
Engineering	Configuration Management	3	CM1, CM2 and CM3
	Requirements Specification and Elicitation	2	ES1 and ES2

The purpose describes the general goal to be achieved and the expected results of the process establish the expected evidence, which must be found in work products produced by the process execution.

In this work, MR-MPS-SW was compared to the C2M model. C2M was proposed in 2014, as a result of a doctoral thesis (FARIAS JUNIOR, 2014). It appeared with the proposal of being a maturity level to support the improvement in the communication of distributed software development teams, constituted based on rigorous scientific methods in its project (FARIAS JUNIOR, 2014). C2M model defines a set of elements (FARIAS JUNIOR et al., 2016; LEITÃO JUNIOR et al., 2017):

- **Maturity Area**: categories which group related maturity factors.
- **Maturity Factor**: describes a communication maturity factor identified during the C2M research and elaboration process.
- **Maturity Level**: a group of maturity factors defined for each level, that is, C2M is defined as a set of factors associated with every maturity level.
- **Goal**: a short description of the goal to be reached by the maturity factor.
- **Practice**: an item that must be satisfied to reach an arbitrary objective. Each practice in C2M is associated with a maturity level and implemented by a maturity factor.

Every maturity level at C2M comprehends a group of communication maturity factors. Furthermore, every factor describes a goal and a set of practices, and every practice is directly associated to a maturity level. Moreover, a set of maturity factors states the organization level based on its associated set of practices implemented at the respective level (FARIAS JUNIOR, 2014).

C2M specifies four maturity levels: (1) Casual (or *ad hoc*); (2) Partially managed; (3) Managed and (4) Reflexive. To reach any level, its criteria must be satisfied, as well as its lower levels must have been reached. C2M resulted in 15 maturity factors and 58 maturity practices, as presented in **Table 2**. Practices in C2M must be performed by organization unities (or processes) to reach a maturity level (FARIAS JUNIOR, 2014).
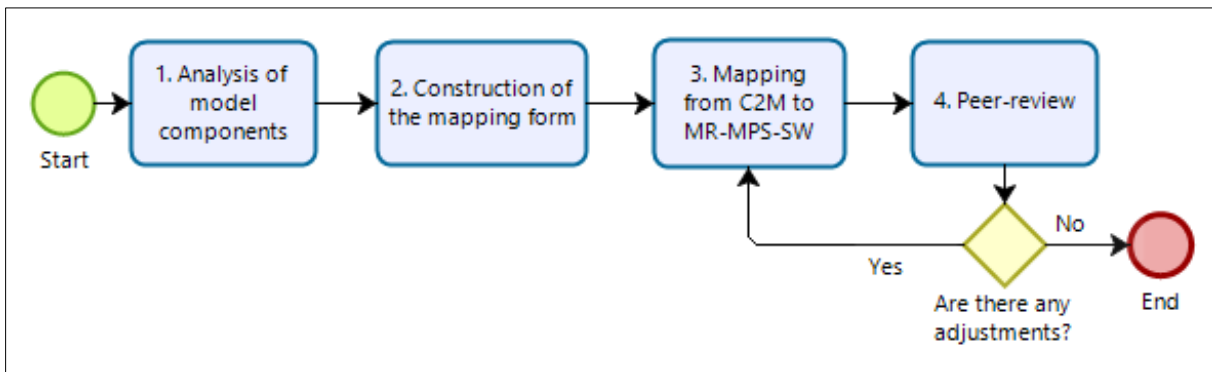
Figure 1. Methodology. Source: Adapted from Mello (2011)

Table 3. Classification criteria. Source: Araujo et al. (2015)

Code	Name	Description
COB	Covered	The origin model covers the requirements of the destiny model.
COB-	Partially covered	The origin model covers some or many aspects of the destiny model.
NOT	Not covered	The origin model does not cover the require ments of the destiny model.

Table 4. Peer review criteria. Source: adapted from Araujo et al. (2015)

Code	Name	Description
TA	High Technical	There was found an issue in an item and, if not altered, it can compromise the considerations.
TB	Low Technical	There was found an issue in an item, and it is convenient to change it.
E	Editorial	A grammatical error was found or the text must be improved.
Q	Questioning	There were doubts about the content of the considerations.
G	General	General comment related to considerations.
AD	Adherent	No problems were found.

RESEARCH METHODOLOGY

Many studies about the mapping between models have already been made (some of them presented in Section 2), however without a definition of the process used to perform it, making them not replicable (BALDASSARRE et al., 2010). A methodology to map two models was proposed by Mello (2011). This methodology was adapted and applied in other works, such as Araujo et al. (2015) and Garcia et al. (2016). An adaptation of this methodology was also used in this work and encompasses activities presented in **Figure 1**.

The process presented in **Figure 1** divides the execution of this work in four activities:

1. **Analysis of the model components**: consisted of an analysis of the models mapped by this work, namely MR-MPS-SW and C2M. This analysis focused on understanding the models, their structures and components, to define the comparison format.

2. **Construction of the mapping form**: aimed in allowing the model components to be described and compared clearly, classifying them according to the criteria defined by Araujo et al. (2015) and shown in **Table 3**, presenting grounds for the classifications.

3. **Mapping from C2M to MR-MPS-SW**: In this activity the results expected from C2M (origin model) are compared to the results expected from MR-MPS-SW (destiny model), identifying agreement and disagreement points between them.

4. **Peer-review**: has as aim to assess the proposed mapping. This review will be performed by specialists in the models, seeking for inconsistencies in the mappings and allowing their corrections. The criteria employed in this step were adapted from Araujo et al. (2015) and are presented in **Table 4**.

PEER REVIEW

The mapping was presented to four specialists in software process improvement and, based on criteria established in **Table 3**, they made their evaluation. **Table 5** presents a summary of the reviewers' experience with software process improvement.

From 199 items which compounded the mapping, 88 were considered "Adherent" (AD) by the assessors; in 90 were found problems of the "High technical" (TA) type, and in 21 were found problems of the "Low technical" (TB) type. No problems with the "Editorial" (E), "Questioning" (Q) or "General" (G) type were pointed by the reviewers. All problems from the TA and TB type were corrected. The results, after adjusts, have gone through a member check performed by reviewer 4 (**Table 5**), aiming to assess the changes performed. According to Sandelowski (2008), member check is a strategy often used to optimize the validity of the results

Table 5. Reviewers' experience summary. Source: The author

Reviewer 1	PhD in Computer Science with 18 years of experience in software process improvement; ISO 9000 assessor; CERTICS assessor; MPS.BR-SW Implementer and assessor; CMMI-SW implementer; and MPT.BR Implementer and Assessor; C2M full specialist.
Reviewer 2	PhD in Computer Science with 10 years of experience in software process improvement; CERTICS assessor; MPS.BR-SV Implementer and asses sor; CMMI-Service implementer; and MPT.BR Implementer and Assessor; C2M full specialist.
Reviewer 3	PhD in Computer Science with 12 years of experience in software process improvement; MPS.BR-SW and MPS.BR-SV Implementer; CMMI Service implementer; and MPT.BR Implementer and Assessor; C2M full specialist.
Reviewer 4	PhD in Computer Science with 9 years of experience in software process improvement. MPS.BR-SW and MPS.BR-SV implementer; MPT.BR implementer and assessor; C2M full specialist

Table 6. Coverage of the maturity factor CD. Source: the author

C2M	MR-MPS-SW	COVERAGE
CD1 - Cultural differences management	GPR 7	COB
	GPR 20 (Starting from level E)	COB
	DFP 8	COB
	GRH 2	COB
	GRH 1	COB
CD2 - Identifying and institutionalizing the cultural context from each project team	GRH 9	COB
	GRH 11	COB
CD3: Establish a cultural knowledge base	GRH 9	COB
	GRH 11	COB
CD4: Standardize project jargon and vocabularies	Not covered.	
CD5: Planning initiatives to mitigate occurrences caused by cultural differences	GRI 6	COB
	GRI 9	COB

in qualitative researches. The other reviewers could not perform the member check due to availability issues. The results after the member check are presented in the next section.

C2M COVERAGE OF MR-MPS-SW

The comparison presented in this section was performed between C2M practices to the results expected from the processes composing the MR-MPS-SW; a mode detailed presentation of these practices and processes can be found in their respective guides: SOFTEX (2016b) and Farias Junior (2014). Details of the mapping are presented in the following sections.

Cultural Difference Management (CD)

The CD maturity factor, from C2M maturity level 2, is composed of two practices: CD1, which deals with the management of cultural differences; and CD2, which treats the identification and institutionalization of the cultural context. The practice CD1 covers (COB) the expected results GPR7 and GRH2 from MR-MPS-SW, which treat, respectively, of the human resources planning and the recruitment of individuals for the project.

The practice CD1 still presents a partial coverage (COB-) for the expected results GPR20 (from the level E - teams establishment and maintaining from rules and guidelines), DFP8 (establishment and maintaining of rules for team structuring, formation and acting) and GRH1 (review of strategic needs of the organization and projects to identify required resources, knowledge and skills). Practice CD2 covers the expected results GRH11 (knowledge provision and sharing) and covers partially (COB-) the expected result GHR9 (knowledge management strategy planning, establishment and maintaining).

At C2M level 3, the maturity factor CD is composed of more three practices: CD3, which treats the establishment of a cultural knowledge base; CD4, which standardizes the project jargon and vocabularies; and CD5, which plan initiatives to mitigate occurrences caused by cultural differences. The practice CD3 totally covers (COB) the expected results GRH9 (a proper strategy for knowledge management is planned, established and maintained to share information in the organization) and GRH11 (knowledge is made available and shared in the organization).

There was found no expected result in MR-MPS-SW which became close to the practice CD4. In turn, practice CD5 partially covers (COB-) the expected results GRI6 (development of risk mitigation plans) and GRI9 (proper actions are executed to correct or avoid the risk impacts, based on its priority, probability, consequences or other defined parameters). **Table 6** resumes the coverage of the maturity factor CD.

Trust Development (TDE)

The maturity factor TDE is present only at level 3 of C2M, and is composed of 3 practices: TDE1, which establishes integration strategies of the stakeholders; TDE2, which treats the member interchange among project dispersed teams; and TDE3, which encourages collaboration and cooperation among teams.

For practice TDE2, there was not found any related item at MR-MPS-SW. In turn, practice TDE1 partially covers (COB-) the expected result GPR 16 (the involvement of the stakeholders in the project is planned, monitored and maintained). Finally, practice TDE3 partially covers (COB-) the expected result GPR 8 - until level F (the resources and workplaces necessary to execute the project are planned). **Table 7** consolidates the coverage information about maturity factor TDE.

Table 7. Coverage of the maturity factor TDE. Source: the author

C2M	MR-MPS-SW	COVERAGE
TDE1: Establish strategies for stakeholders' integration.	GPR 16	COB
TDE2: Member interchange among dispersed project teams.	Not covered.	
TDE3: Encouragement of team collaboration and cooperation.	GPR 8 (Until level F)	COB

Table 8. Coverage of the maturity factor TC. Source: the author

C2M	MR-MPS-SW	COVERAGE
TC1: Adopt synchronous and/or synchronous on-demand tools.	GPR 8 (Until level F)	COB
TC2: Adopt collaboration tools	GPR 8 (until level F)	COB
TC3: Adopt face-to-face communication tools	GPR 8 (Until level F)	COB
	GPR 8 (Until level E)	COB
	DFP 7	COB-

Table 9. Coverage of the maturity factor INF. Source: the author

C2M	MR-MPS-SW	COVERAGE
INF1 - Define infrastructure considering the dispersion level of the team	GPR 8 (Until level F)	COB
INF2 - Periodically monitor the infrastructure	GPR 14	COB
INF3 - Maintain a backup infrastructure	GPR 8 (Until level F)	COB
	GPR 8 (From level E)	COB
	GPR 14	COB
	DFP 7	COB

Communication Support Tools (TC)

The maturity factor TC, at C2M level 2, is composed of two practices, TC1 and TC2, which deal with the adoption of communication and collaboration tools. Both practices (TC1 and TC2) partially cover (COB-) the expected result GPR8 (resource and workplace planning).

At level 3, the maturity factor TC is composed also of the practice TC3, which focuses on the adoption of face-to-face tools. TC3 partially covers (COB-) the expected results GPR 8 - until level F (resources and workplaces necessary to execute the project are planned), GPR 8 - from level E (resources and workplaces necessary to execute the project are planned, starting from standard workplaces of the organization) and DFP 7 (standard workplaces of the organization are established and maintained). **Table 8** shows the coverage of the maturity factor CD.

IT Infrastructure (INF)

The maturity factor INF, at level 2 of C2M, is composed of the practices INF1 (define the infrastructure considering the dispersion level of the team) and INF2 (periodically monitor the infrastructure). INF1 covers (COB) the expected result GPR8 (resource planning and workplaces). INF2 partially covers (COB-) the expected result GPR14, which approaches the monitoring of material and human resources and relevant data of the project.

At level 3, the maturity factor INF is composed also of the practice INF3, which focuses on the maintaining of backup infrastructure. this practice partially covers (COB-) the expected results GPR 8 - until level F (resources and workplaces needed to execute the project are planned), GPR 8 - from level E (material and human resources, as well as relevant project data, are monitored in relation to the planned), GPR 14 (material and human resources, as well as relevant project data, are monitored in relation to the planned) and DFP 7 (the default workplaces of the organization are established and maintained). **Table 9** presents in a summarized form, the coverage of the maturity factor INF.

Geographic Distance Management (GD)

The maturity factor GD is composed, at C2M level 3, of two practices: GD1 (planning and face-to-face meetings) and GD2 (plan and execute frequent communication). There was not found anything similar to the factor GD1 at the expected results of the MR-MPS-SW.

The practice GD2 partially covers (COB-) three expected results: MED7 (communication of the data resulting from analysis), GRH9 (planning, establishment, and maintaining of a knowledge management strategy) and GRH11 (knowledge provision and sharing).

At level 4, the maturity factor GD is composed of two more practices: GD3, which deals with the establishment of a discussion forum in the project; and GD4, which plan initiatives to mitigate occurrences caused by geographic distance. The practice GD3 partially covers (COB-) the expected results GRH10 (a network of experts in the organization is established and a mechanism to support the information exchange between experts and projects is implemented) and GRH11 (knowledge is made available and shared in the organization). While the practice GD4 totally covers (COB) the expected result GRI 6 (risk mitigation plans are developed), and presents a partial coverage (COB-) for the expected result GRI 9 (proper actions are executed to correct or avoid the risk impact, based on its priority, probability, consequence or other defined parameters). **Table 10** consolidates the information about the coverage of the maturity factor GD.

Table 10. Coverage of the maturity factor GD. Source: the author

C2M	MR-MPS-SW	COVERAGE
GD1 - Plan face-to-face meetings	Not covered.	
GD2 - Plan and execute frequent communication	MED 7	COB
	GRH 9	COB
	GRH 11	COB
GD3 - Establish a discussion forum in the project	GRH 10	COB
	GRH 11	COB
GD4 - Plan initiatives to mitigate occurrences caused by geographic distance	GRI 6	COB
	GRI 9	COB

Table 11. Coverage of the maturity factor TD. Source: the author

C2M	MR-MPS-SW	COVERAGE
TD1 - Plan and manage the team synchronization schedules	Not covered.	
TD2 - Plan and execute the continuity of the tasks (transference)	Not covered.	
TD3 - Plan and manage the follow-the-sun strategy (almost continuous development)	GPR10	COB
	GPR8 (Until level F)	COB
TD4 - Plan initiatives to mitigate occurrences caused by temporal distance	GRI 6	COB
	GRI 9	COB

Table 12. Coverage of the maturity factor SM. Source: the author

C2M	MR-MPS-SW	COVERAGE
SM1: Identify the stakeholders	GPR 16	COB
SM2: Define roles and responsibilities	GPR 16	COB
	GPP 3	COB
SM3: Plan the stakeholder management	GPR 16	COB
SM4: Monitor the stakeholders' relationship	GPR 16	COB

Temporal Distance Management (TD)

The maturity factor TD, at level 2 of C2M, is composed of two practices: TD1, which treats of planning and management of the team synchronization schedules, and TD2, which deals with planning and execution of the continuity of the tasks (transference). MR-MPS SW does not have expected results that correspond to these two practices of the factor TD.

At C2M level 3, the maturity factor TD has two more practices: TD3 (plan and manage the follow-the-sun strategy) and TD4 (plan initiatives to mitigate occurrences caused by temporal distance). Practice TD3 partially covers (COB-) the expected results GPR10 (a general plan to execute the project is established with the integration of specific plans) and GPR8 - until level F (resources and workplaces necessary to execute the project are planned). In turn, practice TD4 presents total coverage (COB) for the expected result GRI 6 (plans for risk mitigation are developed), and partially covers (COB-) the expected result GRI 9 (proper actions are executed to correct or avoid the risk impact, based on its priority, probability, consequence or other defined parameters). **Table 11** summarizes the coverage of the maturity factor TD.

Stakeholders Management (SM)

The maturity factor SM, at C2M level 2, also is composed of two practices, SM1 and SM2, which treat, respectively, of the identification of stakeholders and the definition of roles and responsibilities. Either partially cover (COB-) the practice GPR16, which deals with planning, monitoring and maintaining the stakeholders' involvement. SM2 also totally covers (COB) the expected result GPP3 which deals with the establishment of esponsibility and authority in the project management.

At C2M level 3, the maturity factor SM presents one more practice: SM3 (plan the stakeholder management). SM3 totally covers (COB) the expected result GPR 16 (the involvement of the stakeholders in the project is planned, monitored and maintained). Finally, at level 4, one more practice is added to the maturity factor SM: SM4, which deals with monitoring the stakeholders' relationship. SM4 totally covers the expected result GPR 16 (the involvement of the stakeholders in the project is planned, monitored and maintained). **Table 12** presents, in a summarized form, the coverage of the maturity factor SM.

Monitoring Measurement and Analysis (MA)

The maturity factor MA is composed of three practices, all contemplated at C2M level 4: MA1, which establishes the measurement objectives; MA2, which establishes procedures to gather, store and analyze data; and MA3, which deals with the communication of the measurement results. The practice MA1 totally covers (COB) the expected result MED 1 (measurement objectives are established and maintained from the business objectives of the organization and the information needs of technical and management processes). On its turn, the practice MA2 totally covers (COB) the expected results MED 5 (the required data are collected and analyzed) and MED 7 (data and results from the analysis are communicated to the stakeholders and used to support decisions). The practice MA3 totally covers the expected result MED 7 (data and results from the analysis are communicated to stakeholders and used to support decisions). **Table 13** presents, in a summarized form, the coverage of the maturity factor MA.

Table 13. Coverage of the maturity factor MA. Source: the author

C2M	MR-MPS-SW	COVERAGE
MA1: Establish the measurement objectives.	MED 1	COB
MA2: Establish procedures to gather, store and analyze data.	MED 5	COB
	MED 7	COB
MA3: Communicate the measurement results.	MED 7	COB

Table 14. Coverage of the maturity factor CP. Source: the author

C2M	MR-MPS-SW	COVERAGE
CP1: Establish communication strategies	GPR 16	COB
	GRH 9	COB
	GRH 11	COB
CP2: Establish mechanisms to confirm the understanding of the activities.	GRE 1	COB
	GRE 2	COB
CP3: Establish a language standard for the project	Not covered.	
CP4: Establish a communication plan	GPR 10	COB
	GPR 16	COB
CP5: Establish the commitment of the stakeholders to the communication planning	GPR 12	COB
	GPR 16	COB
CP6: Define a communication focal point (communication interlocutor)	Not covered.	
CP7: Project Data (artifacts) management	GPR 9	COB
	GCO 1	COB
	GCO 2	COB
	GCO 6	COB
CP8: Periodically communicate information about the project and team performance.	MED 7	COB
CP9: Plan and manage meetings.	GPR17	COB

Communication Planning (CP)

The maturity factor CP is composed, at C2M level 2, of the following practices: CP1(establish a communication strategy), CP2 (establish mechanisms to confirm the data understanding), CP3 (establish a language standard for the project), CP4 (establish a communication plan), CP5 (establish the commitment of the stakeholders with the communication planning), CP6 (define a communication focus point), and CP7 (project data management).

No expected results which get close to the practices CP3 and CP6 were found at MR-MPS-SW. Practice CP1 partially covers (COB-) the expected results GPR16 (planning, monitoring, and maintaining of the stakeholders), GRH9 (planning, establishment, and maintaining of a knowledge management strategy) and GRH11 (knowledge provision and sharing).

The practice CP2 covers (COB) the expected result GRE1 (obtaining the understanding of requirements together with suppliers), and partially covers (COB-) the expected result GRE2 (requirements evaluation based on criteria and obtaining of a technical team with requirements). Practice CP4 totally covers (COB) the expected result GPR10 (establishment of a general plan for project execution), and partially covers (COB-) the practice GPR16 (planning, monitoring e maintaining of the stakeholders involvement). Practice CP5 covers (COB) the expected result GPR12 which deals with revision and obtaining of commitment with project plans, and partially covers (COB-) the expected result GPR16 (planning, monitoring, and maintaining of the stakeholders' involvement). Finally, practice CP7 totally covers the following expected results: GPR9 (identification and planning about the way to gather relevant data for the project), GCO1 (establishment and maintaining of a configuration management system), GCO2 (identification of configuration items) and GCO6 (control of storage, handling and release of configuration items and baselines).

At C2M level 3, the maturity factor CP presents two more practices: CP8, which deals with periodical communication of information about the project and team performance, and CP9, which deals with planning and management of meetings. The practice CP8 partially covers (COB-) the expected result MED 7 (analysis data and results are communicated to stakeholders and used to support decisions). While practice CP8 presents total coverage (COB) for the expected result GPR17 (reviews are carried out in project milestones and as established in the planning). **Table 14** consolidates the information about the coverage of the maturity factor CP.

Continuous Communication Improvement (CC)

Maturity factor CC has four practices, all met at C2M level 4: CC1, which deals with data gathering; CC2, which provides orientation for use of historical data (establish reliable estimations), CC3, which deals with research, evolution and monitoring of new processes, methods and tools to apply in the organization; and CC4, which establishes, monitors and maintain a strategic plan to improve the communication in the organization.

Practice CC1 totally covers (COB) the expected results: MED 5 (the required data are collected and analyzed) and MED 7 (data and results from the analysis are communicated to stakeholders, and used to support decisions). Practice CC2 partially covers (COB-) the expected results: GPR 4 - until level F (effort and cost to execute tasks and work products are estimated based in historical data or technical references) and GPR 4 - Starting from level E (project tasks planning and estimations are made according to repository estimations and organizational process assets). Practice CC3 totally covers (COB) the expected result AMP 6 (a process improvement implementation plan is defined and executed, and the effects of this implementation are monitored

Table 15. Coverage of the maturity factor CC. Source: the author

C2M	MR-MPS-SW	COVERAGE
CC1: Execute the data gathering	MED 5	COB
	MED 7	COB
CC2: Provide orientation for the use of historical data (establish reliable estimations)	GPR 4 (Until level F)	COB
	GPR 4 (Until level E)	COB
CC3: research, evolution, and monitoring of new processes, methods and tools to apply in the organization.	AMP 6	COB
CC4: Establish, monitor and maintain a strategic action plan to improve communication in the organization	AMP 6	COB

Table 16. Coverage of the maturity factor RM. Source: the author

C2M	MR-MPS-SW	COVERAGE
RM1: Identify communication risks	GPR 6	COB
	GRI 3	COB
	GRI 4	COB
	GRI 6	COB
	GRI 7	COB
RM2: Evolution, categorization and prioritization of communication risks.	GPR 6	COB
	GRI 2	COB
	GRI 3	COB
	GRI 4	COB
	GRI 5	COB
	GRI 7	COB
RM3: Identification of relevant stakeholders as sociated with all risks.	GRI4	COB
RM4: Elaborate risk mitigation plan.	GRI 6	COB
	GRI 9	COB

and confirmed according to the improvement goals). And, finally, practice CC4 totally covers (COB) the expected result AMP 6 (an process improvement implementation plan is defined and executed, and the effects of this implementation are monitored and confirmed according to the improvement goals). **Table 15** consolidates information about the coverage of the maturity factor CC.

Risks Management (RM)

Maturity factor RM is composed, at C2M level 2, of practices RM1 (identify communication risks), RM2 (evolution, categorization, and prioritization of communication risks) and RM3 (identify relevant stakeholders associated with the risks). Practice RM1 partially covers (COB-) the expected result GRI3 which approaches the definition and implementation of strategies for risk management.

The practice RM1 still presents a total coverage (COB) for the following expected results: GPR6 (identification of risks, their impacts, occurrence probability, and treatment priority), GRI4 (risk identification and documentation), GRI6 (development of mitigation plans) and GRI7 (analysis and definition of the application priority of resources for risks). The practice RM2 covers (COB) the expected results GRI2 (determination of the origins and categorization of the risks and definition of parameters to analyze risks), GRI4 (risks identification and documentation) and GRI7 (analysis and definition of priority in the application of resources for risks). The practice RM2 also presents partial coverage (COB-) for the expected results GPR6 (identification of risks, their impacts, probability of occurrence and treatment priority), GRI3 (definition and implementation of strategies for risk management), GRI5 (risk prioritization, estimation e classification). Finally, practice RM3 has partial coverage (COB-) for the expected result GRI4 (identification and documentation of project risks).

At C2M level 3, the maturity factor RM presents one more practice: RM4, which deals with the elaboration of a risk mitigation plan. RM4 totally covers (COB) the expected result GRI 6 (plans for risk mitigation are developed). RM4 presents partial coverage (COB-) for the expected result GRI 9 (proper actions are executed to correct or avoid the risk impact, based on its priority, probability, consequence or other defined parameters). **Table 16** presents, in a summarized way, the coverage of the maturity factor RM.

Communication Patterns and Policies (PP)

The maturity factor PP, at level 2 of C2M, is composed of only one practice: PP1, which establishes a communication policy. PP1 does not present coverage for any result expected from MR-MPS-SW.

At C2M level 3, the factor PP presents one more practice: PP2, which establishes documentation and communication standards. PP2 presents partial coverage (COB-) for the expected results, GPR16 (the stakeholders' involvement in the project is planned, monitored and maintained), GPR22 (a process defined for the project is established according to the strategy for adapting the organization's process) e DFP1 (a defined set of standard processes is established and maintained, together with the indication of applicability of every process). **Table 17** shows, in a summarized way, the coverage of the maturity factor PP.

Table 17. Coverage of the maturity factor PP. Source: the author

C2M	MR-MPS-SW	COVERAGE
PP1: Establish a communication policy	Not covered.	
PP2: Establish documentation and communication standards.	GPR16	COB
	GPR22	COB
	DFP1	COB

Table 18. Coverage of the maturity factor CT. Source: the author

C2M	MR-MPS-SW	COVERAGE
CT1: Plan communication training.	GRH 3	COB
	GRH 4	COB
	GRH 5	COB
CT2: Provide communication training.	GRH 6	COB
CT3: Register communication training.	GRH 6	COB
CT4: Evaluate the benefits of communication training.	GRH 7	COB

Communication Training (CT)

The maturity factor CT is composed, at level 3, of three practices: CT1, which deals with the planning of communication training; CT2, which provides communication training; and CT3, which deals with the register of training in communication. The practice CT1 presents total coverage (COB) for the expected results, GRH 3 (the training activities needs which are responsibility of the organization are identified), GRH 4 (A training strategy is defined, aiming to meet the training requirements of the projects and organization) and GRH 5 (a tactical training plan is defined, aiming to implement the training strategy). The practice CT2 totally covers (COB) the expected result GRH 6 (training activities identified as a responsibility of the organization are conducted and registered). And, finally, practice CT3 totally covers (COB) the expected result GRH 6 (training activities identified as a responsibility of the organization are conducted and registered).

At C2M level 4, maturity factor CT has one more practice: CT4 (evaluate the benefits of communication training). CT4 totally covers (COB) the expected result GRH 7 (training effectiveness is evaluated). **Table 18** summarizes the coverage of the maturity factor CT.

Configuration Management (CM)

All practices of the maturity factor CM are part of level 3 in the C2M. These are CM1, which establishes the control of versions and modifications; CM2, which establishes the access control to configuration items; and CM3, which establishes a configuration plan for the whole project.

The practice CM1 totally covers (COB) the following expected results: GCO 1 (A Configuration Management System is established and maintained), GCO 2 (the configuration items are identified with basis in established criteria), GCO 3 (configuration items subject to formal control are put under baseline), GCO 5 (modifications in configuration items are controlled) and GCO 7 (configuration audits are objectively performed to ensure that baselines and configuration items are complete and consistent). The practice CM1 still presents partial coverage (COB-) for the expected result GCO 4 (the situation of configuration items and baselines is registered along the time and made available).

The practice CM2 partially covers (COB-) the expected result GPR 9 (relevant project data are identified and planned according to the gathering, storage and distribution ways. A mechanism is established to access them, including, if applicable, privacy, and security questions). CM2 still covers partially (COB-) the expected result GCO 6 (storage, handling, and liberation of configuration items and baselines are controlled).

Finally, the practice CM3 partially covers (COB-) the expected results: GPR 9 (relevant data of the project are identified and planned regarding the ways of gathering, storage and distribution. A mechanism is established to access them, including, if applicable, privacy and security questions), and GCO 1 (a Configuration Management System is established and maintained). The practice CM3 still presents total coverage (COB) for the expected results: GPR 10 (a general plan for the project execution is established with the integration of specific plans), GCO 2 (configuration items are identified based on established criteria) and GCO 4 (the situation of configuration items and baselines is registered along the time and made available). **Table 19** presents, in a summarized way, the coverage of the maturity factor CM.

Table 19. Coverage of the maturity factor CM. Source: the author

C2M	MR-MPS-SW	COVERAGE
CM1: Establish the control of versions and modifications.	GCO 1	COB
	GCO 2	COB
	GCO 3	COB
	GCO 4	COB
	GCO 5	COB
	GCO 7	COB
CM2: Establish the access control to configuration items.	GPR 9	COB
	GCO 6	COB
CM3: Establish a configuration plan for the whole project.	GPR 9	COB
	GPR 10	COB
	GCO 1	COB
	GCO 2	COB
	GCO 4	COB

Table 20. Coverage of the maturity factor ES. Source: the author

C2M	MR-MPS-SW	COVERAGE
ES1: Obtain confirmation of the software requirements understanding by the team.	GRE 1	COB
	GRE 2	COB
	DRE 7	COB
	VAL 1	COB
	VAL 2	COB
	VAL 3	COB
ES2: Manage the changes in software requirements	GRE 5	COB
ES3: Maintain the traceability of software requirements.	GRE 3	COB

Requirements Specification and Elicitation (ES)

The maturity factor ES, at level 2 of C2M, is composed of two practices: ES1 (obtain confirmation of the understanding of software requirements by the team) and ES2 (manage changes in software requirements).

The practice ES1 presents coverage (COB) for the following expected results: GRE1 (obtaining of requirement understanding together with requirement suppliers), DRE7 (requirements validation) and VAL1 (identification of work products to be validated). The practice ES1 still presents partial coverage (COB-) for the expected results GRE2 (requirement evaluation based in objective criteria and obtaining of team commitment with requirements), VAL2 (implementation of a validation strategy) and VAL3 (identification of criteria and procedures to evaluation and establishment of a validation environment). The practice ES2 totally covers (COB) the expected result GRE5 (management of requirement changes during the project).

At C2M level 3, the maturity factor ES presents one more practice: ES3, which deals with the maintaining of the software requirements traceability. ES3 totally covers the expected result GRE 3 (bidirectional traceability between requirements and work products is established and maintained). **Table 20** summarizes the coverage of the maturity factor ES.

Overview of the Mapping

The performed mapping allowed to identify that 82,2% of the C2M practices present some kind of coverage for the results expected from MR-MPS-SW. Only the practices GD1, TD1, TD2, CP3, CP6, PP1, CD4 and TDE2 from C2M do not present coverage for MR-MPS-SW. **Table 21** presents the mapping in a summarized way.

Table 21. Summary of the C2M in relation to MR-MPS-SW

C2M	MR-MPS-SW		C2M	MR-MPS-SW		C2M	MR-MPS-SW	
CD1	GPR 7, GRH 2	COB	CD3	GRH 9, GRH 11	COB	CC1	MED 5, MED 7	COB
CD1	GPR 20 (From level E on), DFP 8, GRH 1	COB-	CD4	-	-	CC2	GPR 4	COB
CD2	GRH 11	COB	CD5	GRI 6, GRI 9	COB-	CC3	AMP 6	COB
CD2	GRH 9	COB-	TC3	GPR 8, DFP 7	COB-	CC4	AMP 6	COB
TC1	GPR 8 (Until level F)	COB-	INF3	GPR 8, GPR 14, DFP 7	COB-	MA1	MED 1	COB
TC2	GPR 8 (Until level F)	COB-	GD3	GRH 10, GRH 11	COB-	MA2	MED 5, MED 7	COB
INF1	GPR 8 (Until level F)	COB	GD4	GRI 6	COB	MA3	MED 7	COB
INF2	GPR 14	COB-	GD4	GRI 9	COB-	SM4	GPR 16	COB
GD1	-	-	TD3	GPR10, GPR8 (Until level F)	COB-	CT4	GRH 7	COB
GD2	MED 7, GRH 9, GRH 11	COB-	TD4	GRI 6	COB			
TD1	-	-	TD4	GRI 9	COB			
TD2	-	-	SM3	GPR 16	COB			
SM1	GPR 16	COB-	CP8	MED 7	COB			
SM2	GPR 16	COB-	CP9	GPR17	COB			
SM2	GPP 3	COB	RM4	GRI 6	COB			
CP1	GPR 16, GRH 9, GRH 11	COB-	RM4	GRI 9	COB			
CP2	GRE 1	COB	PP2	GPR16, GPR22, DFP1	COB			
CP2	GRE 2	COB-	ES3	GRE 3	COB			
CP3	-	-	TDE1	GPR 16	COB			
CP4	GPR 10	COB-	TDE2	-	-			
CP4	GPR 16	COB	TDE3	GPR 8 (Until level F)	COB			
CP5	GPR 12	COB	CT1	GRH 3, GRH 4, GRH 5	COB			
CP5	GPR 16	COB-	CT2	GRH 6	COB			
CP6	-	-	CT3	GRH 6	COB			
CP7	GPR 9, GCO 1, GCO 2, GCO 6	COB	CM1	GCO 1, GCO 2, GCO 3, GCO 5, GCO 7	COB			
RM1	GPR 6, GRI 4, GRI 6, GRI 7	COB	CM1	GCO 4	COB			
RM1	GRI 3	COB-	CM2	GPR 9	COB			
RM2	GPR 6, GRI 3, GRI 5	COB-	CM2	GCO 6	COB			
RM2	GRI 2, GRI 4, GRI 7	COB	CM3	GPR 10, GCO 2, GCO 4	COB			
RM3	GRI4	COB-	CM3	GPR 9, GCO 1	COB			
PP1	-	-						
ES1	GRE 1, DRE 7, VAL 1	COB						
ES1	GRE 2, VAL 2, VAL 3	COB						
ES2	GRE 5	COB						

Analyzing the mapping results, there is still possible to notice that the following results expected from MR-MPS-SW are covered (partially or totally) by practices found at C2M:

- Project Management Process: GPR 4, GPR6, GPR 7, GPR 8, GPR 9, GPR 10, GPR 12, GPR 14, GPR 16, GPR 17, GPR 20 (from level E on) and GPR 22;

- Process Definition for the Organizational Process (DFP): DFP 1, DFP 7 and DFP 8;

- Human Resources Management Process: GRH 1, GRH 2, GRH 3, GRH 4, GRH 5, GRH 6, GRH 9, GRH 7, GRH 10 and GRH 11;

- Measurement Process (MED): MED 1, MED 5 and MED 7;

- Project Portfolio Management Process (GPP): GPP 3;

- Requirement Management Process (GRE): GRE 1, GRE 2, GRE 3 and GRE 5;

- Configuration Management Process (GCO): GCO 1, GCO 2, GCO 3, GCO 4, GCO 5, GCO 6 and GCO 7;

- Risk Management Process (GRI): GRI 2, GRI 3, GRI 4, GRI 5, GRI 6, GRI 7, GRI9 and GRI 14;

- Requirement Development Process (DRE): DRE 7;

- Validation Process (VAL): VAL 1, VAL 2 and VAL 3;

- Organizational Process Evaluation and Improvement Process (AMP): AMP 6.

The building of the mapping also allowed us to identify that does not exist a maturity factor at C2M equivalent to only one MR-MPS-SW process. What we can realize at **Table 22** is that a maturity factor at C2M is related to more than one MR-MPS-SW process. For all C2M maturity factors, related processes were found at MR-MPS-SW. However, not all C2M practices (which compose the maturity factors), were contemplated in the expected results of the MR-MPS-SW (which compose the processes). Finally, is possible to realize that the mapped models are not conflicting, but complementary, being C2M partially adherent to MR-MPS-SW.

Table 22. Relationship between C2M maturity factors and MR-MPS-SW processes. Source: the author

C2M		MR-MPS-SW	
ABBREVIATION	MATURITY FACTOR	ABBREVIATION	PROCESS
CD	Management of cultural differences	GPR	Project Management
		GRH	Human Resources Management
		DFP	Organizational Process Definition
TC	Tools to Support Communication	GPR	Project Management
INF	Infrastructure IT	GPR	Project Management
GD	Management of Geographic Distance	MED	Measurement
		GHR	Human Resources Management
SM	Stakeholders Management	GPR	Project Management
		GPP	Projects Portfolio Management
CP	Communication Planning	GPR	Project Management
		GRH	Human Resources Management
		GRE	Requirement Management
		GCO	Configuration Management
RM	Risk Management	GPR	Project Management
		GRI	Risk Management
ES	Requirements Elicitation and Specification	GRE	Requirements Management
		DRE	Requirements Development
		VAL	Validation
TD	Management of Temporal Distance	No Relationship	
PP	Communication Patterns and Policies	No Relationship	

LIMITATIONS AND THREATS

This work has some limitations and threats. The result of the mapping presented in this work was not implanted in an organization. To overcome this limitation, a revision was performed by experts, seeking to avoid misunderstandings. Another limitation of this work is the fact that the mapping was built unidirectionally, that is, only in the C2M to MR-MPS-SW direction. As an evolution of this research, mapping on the contrary direction is also intended.

Since the C2M model is recent, we had difficulties in obtaining a higher participation from senior specialists in the model to perform a review of the mapping, only one of the four specialists which performed the review of the mapping was a senior specialist in the C2M model, and this can be characterized as a threat to this research. Seeking to minimize risks from this threat, we choose full C2M specialists, with notorious experience in software process improvement, and made available to them material sufficient to understand the C2M model in its completeness. The senior C2M specialist had a key role in the review, solving many conflicts that surged in the revision of the others.

CONCLUSIONS

Organizations invest in software process improvement seeking to increase the quality of its products, and, consequently, in augmenting the return from their investments. There are many software process improvement models in the market, with many scopes, and some organizations can find difficulties trying to implement more than on model jointly. In this sense, this work presents a mapping of the process improvement models C2M and MR-MPS-SW.

The most relevant contribution of this work is the confirmation of the adherence of the C2M model to the MR-MPS-SW. In the face of the presented, is possible to confirm the viability of the joint implementation of the two models, without overlapping or prejudice to none of them. The main advantage of the use of this model is to facilitate the implantation of the MR-MPS-SW model in a software company that already has C2M implemented.

The mapping here presented was constructed based on the MR-MPS-SW [SOFTEX 2016b] and C2M [Farias Junior 2014] guides. After built, the mapping was evaluated by four specialists, aiming to identify possible problems. As a result of this evaluation, in 44% of the items the reviewers agreed with the presented mapping, the other items were adjusted according to the suggestions of the reviewers.

After performing the mapping of the models and the peer-review, it was possible to observe that every C2M maturity factor is related to more than one MR-MPS-SW process and that every maturity factor in C2M has related processes in MR-MPS-SW. However, there are C2M practices that do not cover any expected result of MR-MPS-SW.

C2M is an emergent maturity model, still in the consolidation phase. The mapping proposed in this work is part of a larger project, which aims to implant and evaluate C2M in Brazilian software companies, and new results and improvements in the mapping will be found after the ending of the project.

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