Changes in CMMI 2.0 and how they can affect TMMi

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This paper is intended to help TMMi professionals find information about the structure and the process areas of CMMI V2 has changed and could affect future developments around TMMi. It will also help those TMMi practitioners who use TMMi in the organizational context of CMMI V2.

Contents

1 Introduction

The Capability Maturity Model Integration (further: CMMI) was first released in 2000 and used as CMMI v1.1 since August 2002 by a large number of software development companies. In August 2006 CMMI V1.2 appeared, while in November 2010 a major change in structure resulted in version 1.3 of CMMI for Development, CMMI for Acquisition and CMMI for Services.

Due to changes in the organization environment over a decade and community needs, the CMMI Institute launched a complex project to restructure the CMMI model. The main goal was to help improve business performance of the companies using it and to adapt the software process improvement of the companies to the changing business needs. As a result of the project – that lasted longer than initially expected – on March 23rd 2018 Version 2.0 of CMMI Development was released. Release of CMMI V2.1 appeared on December, 4th 2018, including views for Development, Services and Supplier Management.

CMMI V1.3 came to a complete sunset on 30th September 2020.

CMMI V2.0 is an integrated product suite consisting of 5 components that, when used together, provide a clear and proven path to achieving a company's business objectives. The 5 components are: model, training and certification, adoption guidance, appraisal method, systems and tools[1].

The new version of the model resulted in changes in the appraisal opportunities connected to it: benchmarking, sustainment and evaluation appraisals are now possible.

Beginning with 2019 new V2.0 official (most rigorous) appraisals – now named Benchmarking, formerly called SCAMPI A appraisals - based on CMMI V2.0 are accepted by the CMMI Institute. 120[2] appraisals have been conducted according to CMMI V2.0, as statistics from CMMI Institute pages indicate on February, 3rd 2020. Still, most organizations (almost 3200[3]) did SCAMPI A appraisals based on CMMI V1.3 in 2019 and 2020.

However, with all delays and restructuring [4], information made publicly available indicate that CMMI V2.0 is now being accepted by the software development community. This fact makes this new version of the CMMI model even more interesting for the testing community, since TMMi - the most used process improvement models connected to software testing - is positioned as a complementary model to the CMMI (while TMMi can also be used independent of the CMMI model). Actual version of TMMi [5] largely reuses the structure of CMMI V1.3, while it elaborates on the testing-related activities executed in a software or system development company in much more detail than CMMI does.

The testing community has used the TMMi model for many years now, having a complete set of services built around it. A worldwide organization with 22 so-called Local Chapters ensures continuous updating of the model description and training syllabus, while recognized training providers as well as assessments done by accredited (lead) assessors ensure that the model is understood and used by

[1] Source: https://cmmiinstitute.com/cmmi

[2] According to https://cmmiinstitute.com/pars/?StateId=ed7c487f-7b25-4188-9fca-416a17cd142c

[3] Data for CMMI V1.3 appraisals in 2019 and 2020 show around 6500 appraisals; the number is not 100% precise, as data appear both in the old Appraisal System and the new CAS appraisal system. We took into account last published Maturity profile, as well: https://cmmiinstitute.com/getattachment/e328ee92-c9d1-4d05-9df8-bb7926a41d2d/attachment.aspx

[4] Initially it was planned to have end of March 2020 as complete sunset date for CMMI V1.3; this date was moved to 30th September 2020. In the meantime CMMI V2.1 has been released, containing minor updates only https://cmmiinstitute.com/products/cmmi/cmmi-V2-products/release-notes

[5] https://tmmi.org/tm6/wp-content/uploads/2018/11/TMMi-Framework-R1-2.pdf

more and more software and system testing companies worldwide. TMMi Foundation has 2724 members, it certified 1.178 professionals and 131 organizations worldwide [6] .

It is therefore an important question whether TMMi community should consider alignment, or at least learn from, the CMMI V2.0 structure.

In order to facilitate the analysis and decision process regarding this issue, we conducted a systematic review of the CMMI V2.0 changes compared to CMMI V1.3, and of how they could affect TMMi model. In this paper we present the most important findings of this analysis.

The structure of this paper is shown below.

Chapter 2 describes the major changes that CMMI V2.0 contains in comparison to CMMI V1.3. The reader, familiar with CMMI V1.3 and TMMi will understand how the new version of CMMI builds on the previous one, and what major changes in CMMI model concept, structure and architecture were operated.

Chapter 3 is a reflection on the changes presented in Chapter 2, from the point of view of the added business value they might bring.

Chapter 4 elaborates on the changes to testing related practices, goals and process areas, as well as on what exactly are the changes to CMMI process areas that support TMMi process areas. In this context we also looked to structural changes that could be interesting for a new version of TMMi.

In Chapter 5 we show what changes, in our opinion, could be or should be studied in detail at a later stage in the context of TMMi 2.0. Finally, we give a list of References; These were used during the study that resulted in this paper. In some cases information from the references were used; in such cases we explicitly mention the source (e.g,. of tables or figures).

2 Major changes in CMMI V2.0

CMMI V2.0[7] is defined as "an integrated product suite consisting of 5 components that, when used together, provide a clear and proven path to achieving a company's business objectives"[8].

2.1 Elements of CMMI V2.0

The elements of CMMI V2.0 are (see Figure 1): model, appraisal method, training and certifications, systems and tools, adoption guidelines. It is a change in viewpoint - compared to CMMI V1.3 - to consider CMMI as an integrated product suite, in which the process improvement model, approach, appraisal method, training and certification, as well as the adoption guidelines are all components, complementing each other and facilitating each other's usage.

The *model* description, its elements and structure were basic for all those using CMMI V1.3 in the context of process improvement, as well as in using the model as an input for TMMi. Therefore, we focus here mostly on the elements of the CMMI V2.0 *model.* Later in this chapter we shortly present some aspects of the *new appraisal method*[9], and we mention the *set of tools* usable in the context of CMMI V2.0. We do not touch, however, the aspects of training & certification or adoption guidelines.

[6] According to tmmi.org data, October, 9th 2020

[7] CMMI V2.0 is the branding of the current framework. Technically speaking the most current version of this is CMMI V2.1. As the model is updated there are version updates (CMMI V2.x). But, for simplicity sake we generally speak of "CMMI V2.0" appraisals/training/framework.

[8] Source: https://cmmiinstitute.com/cmmi

[9] This may also be interested in the context of updating TAMAR (TMMi Assessment Method Application Requirements). However, it is the subject of an other investigation, outside the scope of this paper.

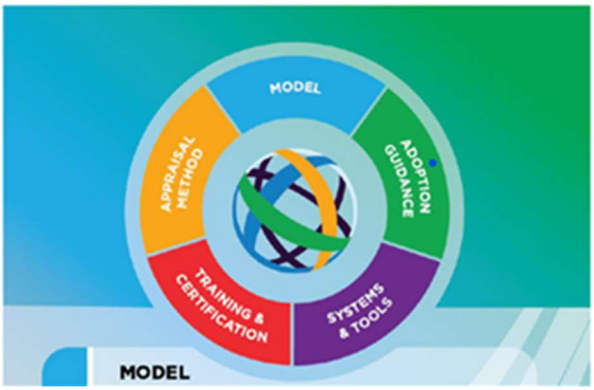

Figure 1. : Elements of CMMI V2.0 Source: https://cmmiinstitute.com/cmmi

CMMI Institute has developed an information package publicly available that describes many aspects of CMMI V2.0.

The text of the actual chapter reflects *our view* on the elements we consider most important – without diminishing the importance of further elements.

2.1.1 CMMI V2.0 architecture

The **architecture of the model** is described on CMMI Institute web pages, accessible for partners, based on licenses [10]. Full model description is available in English, Chinese, Japanese, Spanish, Portuguese and French[11]. The model viewer tool provides all the information in a well-structured, easy-to-use way.

The basic components of the CMMI 2.0 model are: Practice Areas, Views (containing Capability Areas, Categories for Capability Areas) , Practice Groups, Practices and Informative Materials. Short definition of these are listed here, while details are given in 2.1.2.

View is a selection of a set of model components, important to and selected by end user or predefined by the CMMI Institute. Predefined views are: CMMI Development, CMMI Services, CMMI Supplier Management. Predefined views include predefined model views, capability area views, etc. Predefined model views include CMMI-DEV, CMMI-SVC, CMMI-SPM, CMMI-PPL.

> **Capability Area:** A group of related Practice Areas (preciously called process areas) that can provide improved performance in the skills and activities of an organization or project. Capability Areas are a type of view.
>
> **Categories** for Capability Areas: are logical groups or views of related Capability Areas that address common problems encountered by business when producing or delivering solutions. Categories are, in fact, type of views.

Practice Group: within Practice Areas, the practices are organized into a set of evolutionary levels, labeled Level 1, Level 2, etc. (up to Level 5), which provide a path for performance improvement. Each evolutionary level builds on previous levels by adding new functionality or sophistication resulting in increased capability.

[10] https://cmmiinstitute.com/dashboard The model is downloadable by registered CMMI Institute partners , in .pdf format, read-only , without possibility of copying.
[11] As on 30.September 2020.

Practice: the practices consist of Required Practice Information (intent , value, additional required practice information) and Explanatory Practice Information.

Practice Area is a collection of similar practices that together achieve the defined intent, value and required information described in that Practice Area.

Practice Areas (PAs) and Practices contain **required** and **explanatory information.** For Practice Areas the required information are: Intent statement, Value statement and Additional Required Information must be defined. Likewise, for practices, the required information are: Practice statement, Value statement and Additional Required Information. Everything other than the required information is **informative material**. However, CMMI V2.0 explicitly mentions that the *informative material of the model cannot be ignored*; it is needed to understand the meaning of the required information of the model.

Maturity Levels are very similar to Maturity Levels in CMMI V1.3. However, a Maturity Level 0 has been introduced, where the company is characterized by an unknown and ad-hoc way of doing things, when the work may or may not get done. The 6 Maturity Levels are named *Incomplete, Initial, Managed, Defined, Quantitatively Managed* and *Optimizing*.

Core and domain-specific Practice Areas were defined.

2.1.2 From the abstract level to the concrete

There are 4 Categories, 10 Capability Areas and 25 Practice Areas, out of which 18 are Core Practice Areas. There are in total 6 domains identified to have domain-specific Practice Areas, namely: Development (DEV), Services (SVC), Supplier Management (SPM), Security, Safety and People Management. Some are finalized, some under development, some marked as being planned to develop in the future.

Here we list the Core and the DEV Practice Areas. Details to be found in the CMMI V2 model descriptions.

Category	Capability Area		Practice Area	
Doing	**Ensuring Quality**	**ENQ**	Requirements Development & Management	RQM
			Process Qquality Assurance	PQA
			Verification and Validation	VV
			Peer Review	PR
	Engineering & Developing Products	**EDP**	Technical solution	TS
			Product Integration	PI
	Selecting & Managing Suppliers	**SMS**	Supplier Angreement Management	SAM

Category	Capability Area		Practice Area	
Managing	Planning & Managing Work	PMW	Estimating	EST
			Planning	PLAN
			Monitor and Control	MC
	Managing Business Resilience	MBR	Risk and Opportunity Management	RSK
	Managing the Workforce	MWF	Organizational Traning	OT
Enabling	Supporting Implementation	SI	Causal Analysis and Resulution	CAR
			Decision Analysis and Resolution	DAR
			Configuration Management	CM
Improving	Sustaining Habit and Persistence	BSC	Governance	GOV
			Implementation Infrastucture	II
	Improving Performance	IMP	Process Management	PCM
			Process Asset Development	PAD
			Managing Performance and Measurement	MPM

Figure 2. : CMMI V2 architecture and Practice Area organization

The 4 Categories are: doing, managing, enabling and improving. As these categories emphasize some of the key relationships that exist among the practice areas, they could be regarded as a grouping similar to the engineering, support, project management and organizational process area categories in CMMI V1.3.

Extremely important is the Sustaining Habit & Persistence Capability Area with the Practice areas Governance and Implementation Infrastructure, as these practice areas replace the Generic Goals and Generic Practices from CMMI V1.3. Further details connected to this Capability Area are described in section 2.1.4.

2.1.3 Evolutionary levels, Capability Levels and Maturity Levels

In CMMI V2.0 the concept of capability and Maturity Level is implemented via the so called “evolutionary level”.

Evolutionary level is a characteristic *within* one practice area. For the same Practice Area, different levels contain different depth of the practices' sets.

According to this, at **Level 1** of a Practice Area has practices in place that ensure a simple approach to meeting intent of practice area. This is not a complete set of practices to achieve the full intent of the practice area. However, performance issues are already addressed. At **Level 2** a simple, but *complete* set of practices are in place that address the *full intent* of the PA. At this level CMMI V2 does not require the use organizational assets, but it is a requirement to achieve performance objectives. At **Level 3** a Practice Area is characterized by the fact that it uses organizational standards & tailoring to address work characteristics, uses organizational assets and a focus on achieving performance objectives. At **Level 4** the PA is characterized by the usage of statistical and other quantitative techniques to detect, refine, or predict the area of focus to achieve quality and process performance objective. At **Level 5** the PA uses statistical and other quantitative techniques to optimize to achieve quality and process performance objectives.

One can note that "Evolutionary level" is very similar to the CMMI V1.3 concept of *Capability level*, that was initially associated to Process Areas by the continuous approach of CMMI, and it is characteristic to other Software Process Improvement models using a continuous approach (such as Automotive SPICE[12]).

Maturity levels refer to the evolutionary levels within the organization. There are practice areas associated with each Maturity Level. The term "High Maturity" involves the use of statistical and other quantitative techniques on selected processes. Maturity levels 4 and 5 imply that the organization has a deeper understanding of the processes used.

Although it is not explicitly stated, CMMI V2.0 is *more a continuous model than a staged one*.

An important change is that already at Level 1 ***all*** Practice Areas are present. The difference among the different levels (of maturity) is not any more in the Practice Areas required on that level, but in the practices of each Practice Area needed at that level. Thinking of CMMI V1.3, this would be somehow similar to the idea that a Process Area has different Specific Practices associated to different Maturity Levels, while all Process Areas would have a set of practices required already in the beginning. It is, for example, as if Product Integration (PI) or Risk Management (RSKM) of CMMI V1.3 would be required already at Maturity Level 2 having some basic practices already in place, while more sophisticated practices would be added for, Maturity Level 3, Maturity Level 4 and so on.

While all Practice Areas have practices associated to Level 1 and Level 2, only some Practice Areas have practices associated to Level 3 (all Practice Areas, except Configuration Management) , Level 4 (Planning, Supplier Agreement Management, Causal Analysis and Resolution, Managing Performance & Measurement, Process Management, Governance) and Level 5 (Causal Analysis and Resolution, Managing Performance & Measurement).

Core Practice Areas, indicating the levels on which they have practices is presented in Figure 3.

The notion of equivalent staging is not emphasized any more (it disappeared from the model). An organization will progress through 6 Maturity levels, through 4 stages of process discipline. Stage 1 is called *Unconsciously Ad Hoc*, when process execution is ad hoc and undisciplined. At stage 2, characterized as *Consciously Ad Hoc*, the conscious execution of the processes is ad hoc and unrecorded, fact that limits the degree of performance improvement. On Stage 3 the organization ensures recording of its processes and a fidelity of process execution is always ensured. This stage is

[12] http://www.automotivespice.com/fileadmin/software-download/Automotive_SPICE_PAM_30.pdf

characterized as *Consciously Disciplined*. Stage 4 is called *Unconsciously Disciplined*, processes and performance are clearly understood, followed always, by everyone.

Core Practice Areas	Level 1	Level 2	Level 3	Level 4	Level 5	
Estimating	1	2	3			CORE
Planing	1	2	3	4		
Monitor and Control	1	2	3			
Supplier Agreement Management	1	2	3	4		
Causal Analysis and Resolution	1	2	3	4	5	
Decision Analysis and Resolution	1	2	3			
Configuration Mamagement	1	2				
Managing Performance and Measurement	1	2	3	4	5	
Process Management	1	2	3	4		
Process Asset Development	1	2	3			
Requirements Development and Management	1	2	3			
Process Quality Assurance	1	2	3			
Verification and Validation	1	2	3			
Peer Reviews	1	2	3			
Risk and Opportunity Management	1	2	3			
Organizational Taining	1	2	3			
Govermance	1	2	3	4		
Imlementation Infrastructure	1	2	3			

Figure 3. : Elements of CMMI V2.0 shown by Maturity Level.
Based on: https://cmmiinstitute.com/cmmi

2.1.4 Process Persistence and Habit versus Generic Goals and Generic Practices

The change that is probably most difficult to understand by the Software Process Improvement specialists is the fact that Generic Goals and Practices have disappeared from CMMI V2.0. In the CMMI model, the term "persistent and habitual" describes now the routine way of doing business and following and improving processes that an organization uses. These terms came to replace the notion of “institutionalization”.

Persistence is defined as "firm or stubborn continuance in a course of action despite difficulty or opposition". **Habit** is **"**a tendency or practice, especially one that is hard to give up". The higher the maturity of a company is, the more persistent and habitual will the processes be executed.

The model contains a Capability Area named **Sustaining Habit and Persistence** (SHP). This is to enable a persistent and habitual organizational culture.

SHP practices address two Practice areas: Governance (GOV) and Implementation Infrastructure (II). GOV contains practices to be performed by the senior management in order to promote business-oriented strategy, processes defined accordingly, and the uniform way of working. Strategy setting, planning at business level, monitoring the performance of all the processes, providing adequate resources and reinforcing and rewarding the development and use if processes are practices of this Practice Area. Implementation Infrastructure (II) Practice Area describes the infrastructure needed to build, follow, sustain and improve processes over time.

The infrastructure includes process descriptions, resource availability, funding, training and objective process evaluation.

The Governance and Implementation Infrastructure Practice Areas integrate, in fact, all the former Generic Goals and Generic Practices. Having no Generic Goals and Generic Practices any more, made it useless to keep the notions on Specific Goals and Specific Practices. Therefore in CMMI V2.0 only the notion of Practices exists (that are, in most cases, similar to the Specific Practices in CMMI V1.3, but in the cases of GOV and II they replace the CMMI V1.3 Generic Goals and Generic Practices).

The benefits will be to reduce the complexity of the model and make V2.0 easier to understand and implement. GOV requires the high-level management should take their duty during improvement process. II will help allocate the infrastructure during the process improvement implementation.

In this way, organizations could focus the work unit (project) and organization's attention on making their processes a persistent habit.

3 What Business Values does CMMI V2.0 Bring?

In this part we give a description of the business value the changes found in CMMI V2.0 compared to CMMI V1.3 might bring. We do not list all changes, but those we consider important in the sense that they could affect the TMMi model.

3.1 Business value of the conceptual and architectural changes

The **business value** of the conceptual and architectural changes is in the simplified way of presenting the concepts of evolution of a company through different stages of maturity and process capability. Levels of consciousness, as well as the notion of disciplined process execution is easier understood by the management. The way of presenting these ideas within the model description is now closer to the practitioners.

When thinking about the **business value** of having Process Persistence and Habit versus Generic Goals and Generic Practices, one must understand that Generic Goals and Generic Practices in CMMI 1.3 were necessary but were often not given sufficient attention in implementation. Generic Goals and Generic Practices in CMMI 2.0 become Practice Areas, which avoids duplication and emphasizes the meaning of the processes in the organization. This has a huge impact on the evaluation scores of the organization being appraised, so its importance is enhanced. Generic Goals and Generic Practices were the basis for an organization to implement CMMI, and now their importance increases, having two new Practice Areas replacing them. This will force the organizations to re-examine their infrastructures, which can help CMMI to be better integrated into the organization.

3.2 Adding new "View" concept

View means from the end-customer perspective a set of predefined important Practices or Practice Areas. These can be selected by the customer or predefined by the CMMI® Institute.

CMMI® Institute predefined views include: CMMI Development V2.0, CMMI Service V2.0, CMMI Supplier Management V2.0.

Any other combination of Practice Areas, Capability Areas or Practice Groups is possible.

Thinking about the **business value**, we can state that with this change CMMI 2.0 continues to help organizations understand and enhance their capabilities in all areas, with the goal to gain better, faster business results. The updates in this direction to CMMI V2.0 provide the following benefits in each area:

- Development: Improve an organization's capability to develop quality products and solutions that meet the needs of customers and end users.
- Services: Improve an organization's capability to efficiently and effectively deliver quality service offerings that meet market and customer needs.
- Supplier Management: Reduce enterprise risk and improve supply chain management capability.

3.3 Changing Process Area to Practice Area

The name Process Area might have caused the misunderstanding that there was a sequential relationship between Process Areas, but in fact this is not true. After changing Process Area to Practices Area, this misunderstanding is avoided.

The **business value** here is that this change emphasizes that CMMI V2.0 is a collection of *best practices* rather than a collection of processes to be implemented. Also, it can be mentioned as an added value of the change that the term "process" is less popular in the Agile community.

3.4 Grouping Practice Areas into Capability Areas

The changes of the new CMMI version include not only adding the new concept of Capability Area, but also grouping Practice Areas into Capability Areas. The definition of Capability Area (CA) is given in 2.1.1. As mentioned in 2.1.2, there are four categories of capability areas: Doing, Managing, Enabling and Improving. Each CA category includes several capability areas, and each capability area includes several PAs (Practice Area), which shows a *clearer path* to *capability building and improvement*. The name of a CA generally *stresses* solving a certain type of problem. For example, a CA named ENQ stands for Ensuring Quality, and it stresses "to develop and manage high quality requirements and products". Under this CA, there are four practice areas: Requirements Development & Management (RDM), Process Quality Assurance (PQA), Verification and Validation (VV), Peer Review (PR). One of the major benefits is that from the capability view dimension an organization can easier identify where they have performance gaps, and it is easier to apply the practice areas under that CA to improve the capability of their people, process and technology.

Business value of this change is that Category and Capability Areas show a clearer path for capability building and improvement. Category helps the organization to clarify which category of goal they want to achieve. The CA generally stresses solving a certain type of problem. Category and Capability allow companies to fully understand their capabilities and problems, and to make choices in 10 different Capability Areas, to identify the scope and content of improvements. For Practice Areas within a Capability Area there is a continuous improvement, in accordance with business requirements. This will help the organization to build a more comprehensive, integrated management system.

3.5 Improvement benefits and the obtained value - strongly emphasized in CMMI V 2.0

In CMMI V1.3, only on higher Maturity Levels the process improvement is driven by business objectives. In CMMI 2.0 in each Practice Area a new element is added, called "Value", which describes the value of that practice. This change reflects the business objective driven improvements. For example, in CA ENQ (Ensuring Quality), within the Practice Area RDM (Requirements Deployments and Management), there is the statement of Value: "To ensure the customer requirements and expectations get satisfied." In CA ENQ, the PR (Peer Review) there is the statement of Value: "To identify problems or defects as earlier as possible, reducing cost and re-work".

When thinking about the business value of this change, one must consider that in CMMI1.3, the principle of "value-driven" was not very clear. Although "value" was mentioned in the model and evaluation methods, it was largely submerged in the use of hundreds of pages of model description and evaluation-driven models. This change is a landmark improvement of CMMI 2.0, as it not only enables enterprises to understand the practical value of the model, but also makes it clear that this is the goal that the organization should pursue. It comprehensively emphasizes the *intent and value of the model content* at all levels. The model recommendation is to do what the enterprise needs, because it can help the enterprise solve the problem and bring the benefits in return.

3.6 Grading practices on different levels

This is the evolutionary architectural characteristic within each Practice Area. For the same Practice Area, different levels contain practices sets of different depth. For example: while CAR (Causal Analysis & Resolution) appeared on ML5 in CMMI V1.3, it is now a recommendation that organizations on levels 1,2,3 also perform CAR practices, but with different analysis methods and means compared with organization in level 4 and level 5. On level 2 the model requires selecting results to analysis and causal analysis. On Level 4, the model requires using statistical and other quantitative method to do the casual analysis for the selected results.

Business value of this change lies in bringing clearer and a more methodical path for building capability and improving. It simplifies the adoption and measurement. More organizations can adopt the model in a manner that better fits their specific and unique needs.

4 Changes Affecting Test-Related Practices in CMMI V2

As noted previously the CMMI V2.0 model structurally has considerably changed. However, testing-related practices have remained in the new version. They have been partly restructured, and completed.

These practices appear in the Practice Areas of Peer Review and Verification & Validation of the Capability Area Ensuring Quality, as well as within the Practice Area Product Integration of the Capability Area Engineering and Developing Projects.

Remarkable that Peer Reviews has again a separate Process Area (while in CMMI V1.3 it was included within a Specific Goal in the Verification process area).

Below we present a short analysis of the changes observed in testing-related processes in CMMI V2. In our analysis we made use of the data published by CMMI Institute, as "a detailed list of CMMI V2 mapping to previous CMMI V1.3 constellation practices" (https://cmmiinstitute.com/resource-files/public/v2-0-materials) . We present here only the elements related to CMMI-DEV v1.3 constellation.

In the following we present a table with **Peer Reviews (PR)** practices existing in CMMI V2 as mapped to CMMI V1.3.

Practice Area in CMMI V2	ML	Practice #	Practice Name	CMMI-DEV V1.3
Peer Reviews (PR)	Level 1	PR 1.1	Perform reviews of work products and record issues.	
Peer Reviews (PR)	Level 2	PR 2.1	Develop and keep updated procedures and supporting materials used to prepare for and perform peer reviews.	
Peer Reviews (PR)	Level 2	PR 2.1	Develop and keep updated procedures and supporting materials used to prepare for and perform peer reviews.	VER SP 2.1
Peer Reviews (PR)	Level 2	PR 2.2	Select work products to be peer reviewed.	
Peer Reviews (PR)	Level 2	PR 2.2	Select work products to be peer reviewed.	VER SP 1.1
Peer Reviews (PR)	Level 2	PR 2.3	Prepare and perform peer reviews on selected work products using established procedures.	VER SP 2.1
Peer Reviews (PR)	Level 2	PR 2.3	Prepare and perform peer reviews on selected work products using established procedures.	VER SP 2.2
Peer Reviews (PR)	Level 2	PR 2.4	Resolve issues identified in peer reviews.	
Peer Reviews (PR)	Level 2	PR 2.4	Resolve issues identified in peer reviews.	VER SP 2.3
Peer Reviews (PR)	Level 3	PR 3.1	Analyze results and data from peer reviews.	
Peer Reviews (PR)	Level 3	PR 3.1	Analyze results and data from peer reviews.	VER SP 2.3

Table 1.: Mapping CMMI V2 PR practices to CMMI-DEV v1.3.
Source: https://cmmiinstitute.com/resource-files/public/v2-0-materials

It can be seen that Peer Review practices are present from Level 1 through Level 3. There is no special indication on the type of work products that should be peer reviewed on Level 1. Preparation and performing Peer Reviews is a Level 2 requirement, while analyzing data from peer reviews stays now on Level 3 (where the entire process of Peer Reviewing was required in CMMI V1.3). It is a completely new practice now (required on Level 1) to "Perform reviews of work products and record issues". A new practice for DEV, required at Level 2 is to "Develop and keep updated procedures and supporting materials used to prepare for and perform peer reviews". However, this practice was present in CMMI-SVC 1.3. in SSD. The remainder of the CMMI V2 PR practices have correspondents in CMMI -DEV v1.3.

Next, let us look to the **Verification and Validation (VV)** process**.** First, one remarks that the process areas of CMMI V1.3 known as Verification (VER) and Validation (VAL), previously required at ML3 are now combined into one single process, which has practices from Level 1 to Level 3. The mapping is shown in Table 2.

Practice Area in CMMI V2	ML	Practice #	Practice Name	CMMI-DEV V1.3
Verification and Validation (VV)	Level 1	VV 1.1	Perform verification to ensure the requirements are implemented and record and communicate results.	
Verification and Validation (VV)	Level 1	VV 1.1	Perform verification to ensure the requirements are implemented and record and communicate results.	VER SP 3.1

Practice Area in CMMI V2	ML	Practice #	Practice Name	CMMI-DEV V1.3
Verification and Validation (VV)	Level 1	VV 1.2	Perform validation to ensure the solution will function as intended in its target environment and record and communicate results.	
Verification and Validation (VV)	Level 1	VV 1.2	Perform validation to ensure the solution will function as intended in its target environment and record and communicate results.	VAL SP 2.1
Verification and Validation (VV)	Level 2	VV 2.1	Select components and methods for verification and validation.	
Verification and Validation (VV)	Level 2	VV 2.1	Select components and methods for verification and validation.	VAL SP 1.1
Verification and Validation (VV)	Level 2	VV 2.1	Select components and methods for verification and validation.	VER SP 1.1
Verification and Validation (VV)	Level 2	VV 2.2	Develop, keep updated, and use the environment needed to support verification and validation.	
Verification and Validation (VV)	Level 2	VV 2.2	Develop, keep updated, and use the environment needed to support verification and validation.	VAL SP 1.2
Verification and Validation (VV)	Level 2	VV 2.2	Develop, keep updated, and use the environment needed to support verification and validation.	VER SP 1.2
Verification and Validation (VV)	Level 2	VV 2.3	Develop, keep updated, and follow procedures for verification and validation.	
Verification and Validation (VV)	Level 2	VV 2.3	Develop, keep updated, and follow procedures for verification and validation.	VAL SP 1.3
Verification and Validation (VV)	Level 2	VV 2.3	Develop, keep updated, and follow procedures for verification and validation.	VER SP 1.3
Verification and Validation (VV)	Level 3	VV 3.1	Develop, keep updated, and use criteria for verification and validation.	
Verification and Validation (VV)	Level 3	VV 3.1	Develop, keep updated, and use criteria for verification and validation.	VAL SP 1.3
Verification and Validation (VV)	Level 3	VV 3.1	Develop, keep updated, and use criteria for verification and validation.	VER SP 1.3
Verification and Validation (VV)	Level 3	VV 3.2	Analyze and communicate verification and validation results.	
Verification and Validation (VV)	Level 3	VV 3.2	Analyze and communicate verification and validation results.	VAL SP 2.2
Verification and Validation (VV)	Level 3	VV 3.2	Analyze and communicate verification and validation results.	VER SP 3.2

Table 2.: Mapping CMMI V2 VV practices to CMMI-DEV v1.3.
Source: https://cmmiinstitute.com/resource-files/public/v2-0-materials

One can notice that VV practices are required now starting with Level 1. “Perform verification / validation to ensure the requirements are implemented and record and communicate results” is a first requirement, followed by „Perform validation to ensure the solution will function as intended in its target environment and record and communicate results”. New requirements in DEV have been added at Level 2, and refer to development, keeping updated, and following procedures for verification and validation. Requirements present in CMMI V1.3 related to selection of the components to be verified / validated the preparation of the verification / validation environment are now required at Level 2. Development, keeping updated, and using criteria for verification and validation are present at Level 3 ,

while analysis and communication of VV results is a Level 3 requirement. As a general conclusion the various practices in CMMI 2.0 are still on a high level when it comes to testing. Finally, let us analyze the Product Integration requirements from CMMI V2. The mapping is shown in Table 3.

Practice Area in CMMI V2	ML	Practice #	Practice Name	CMMI-DEV V1.3
Product Integration (PI)	Level 1	PI 1.1	Assemble solutions and deliver to the customer.	
Product Integration (PI)	Level 2	PI 2.1	Develop, keep updated, and follow an integration strategy.	PI SP 1.1
Product Integration (PI)	Level 2	PI 2.2	Develop, keep updated, and use the integration environment.	PI SP 1.2
Product Integration (PI)	Level 2	PI 2.3	Develop, keep updated, and follow procedures and criteria for integrating solutions and components.	PI SP 1.3
Product Integration (PI)	Level 2	PI 2.3	Develop, keep updated, and follow procedures and criteria for integrating solutions and components.	PI SP 3.2
Product Integration (PI)	Level 2	PI 2.4	Confirm, prior to integration, that each component has been properly identified and operates according to its requirements and design.	PI SP 3.1
Product Integration (PI)	Level 2	PI 2.5	Evaluate integrated components to ensure conformance to the solution's requirements and design.	PI SP 3.3
Product Integration (PI)	Level 2	PI 2.6	Integrate solutions and components according to the integration strategy.	
Product Integration (PI)	Level 2	PI 2.6	Integrate solutions and components according to the integration strategy.	PI SP 3.2
Product Integration (PI)	Level 2	PI 2.6	Integrate solutions and components according to the integration strategy.	PI SP 3.4
Product Integration (PI)	Level 3	PI 3.1	Review and keep updated interface or connection descriptions for coverage, completeness, and consistency throughout the solution's life.	PI SP 2.1
Product Integration (PI)	Level 3	PI 3.1	Review and keep updated interface or connection descriptions for coverage, completeness, and consistency throughout the solution's life.	PI SP 2.2
Product Integration (PI)	Level 3	PI 3.2	Confirm, prior to assembly, that component interfaces or connections comply with interface or connection descriptions.	
Product Integration (PI)	Level 3	PI 3.2	Confirm, prior to integration, that component interfaces or connections comply with interface or connection descriptions.	PI SP 2.2
Product Integration (PI)	Level 3	PI 3.2	Confirm, prior to integration, that component interfaces or connections comply with interface or connection descriptions.	PI SP 3.1
Product Integration (PI)	Level 3	PI 3.3	Evaluate integrated components for interface or connection compatibility.	

Table 3.: Mapping CMMI V2 PI practices to CMMI-DEV v1.3.
Source: https://cmmiinstitute.com/resource-files/public/v2-0-materials

We can notice that the Practice Area of Product Integration has requirements regarding its performance starting with Level 1, and continues to have requirement on Level 2 and Level 3. This Practice Area has some new requirements compared to the its previous version in CMMI V1.3: Confirm, prior to assembly, that component interfaces or connections comply with interface or connection descriptions, and "Evaluate integrated components for interface or connection compatibility".

Summarizing the previous information, we can state that testing-related processes and practices have in CMMI V2 a slightly different distribution over the capability and maturity levels than they had in CMMI V1.3. Basically, the performance of the testing-related practices is encouraged from the very beginning of a process improvement, requirements being present already at Level 1. This is a positive change.

However, detailed requirements or implementation guidelines connected to testing are not provided in CMMI V2. Elements related at least to testing strategy, testing policy, test environment, test organization, testing techniques, nonfunctional testing are still missing, and elements connected to test design and execution are not made explicit in the model.

Table 4 summarizes the mapping among TMMi Process Areas and CMMI V2 Capability Areas and Practice Areas.

TMMi Level	**TMMi Process Area**	**CMMI ML V1.3**	**Process Area**	**CMMI V2.0 Capability Area**	**CMMI V2 Practice Area**
L2	2.1 Test Policy and Strategy	2	MA	Improving – Improving Performance	Managing Performance & Measurement
L2	2.2. Test Planning	2	PP REQM L3 RSKM	Managing – Planning & Managing Work Managing – Managing Business Resilience	Planning Estimating Risk & Opportunity Management
L2	2.3 Test Monitoring and Control	2	PMC RSKM	Managing – Planning & Managing Work Managing – Managing Business Resilience	Monitoring & Control Risk & Opportunity Management
L2	2.4 Test Design and Execution	2	REQM		
L2	2.5 Test Environment	2	RD		
L3	3.1 Test Organization	3	OPF		
L3	3.2 Test Training Program	3	OT	Managing the workforce	Organization training
L3	3.3 Test Lifecycle and Integration	3	PP REQM L3 RSKM		

TMMi Level	TMMi Process Area	CMMI ML V1.3	Process Area	CMMI V2.0 Capability Area	CMMI V2 Practice Area
L3	3.4 Non-Functional Testing	3	REQM		
L3	3.5 Peer Review	3	VER	Doing – Ensuring Quality	Peer Review
L4	4.1 Test Measurement	4	MA		
L4	4.2 Product Quality Evaluation	4	QPM		
L4	4.3 Advanced Peer Review	4	N/A		
L5	5.1 Defect Prevention	4	CAR		
L5	5.2 Quality Control	4	OPP		
L5	5.3 Test Process Optimization	4	OID		

Generic Goals 2	CMMI v1.13 L2 CM PP PPQA	CMMI V2.0 : included into II and GOV . Needs further study.
Generic Goals 3	CMMI L2 MA CMMI L3 OPD OPF	CMMI V2.0 –included into II and GOV. Needs further study.

Table 4.: Mapping TMMi processes to CMMI V2

Although this analysis was not complete, TMMi requirements connected to test processes are clearly much more detailed that CMMI V2 requirements. While it is of high importance that CMMI V2 emphasizes the need for execution of testing-related practices already at Level 1, and structures the testing practices to evolve over Level 1, Level 2, Level 3, further, more detailed requirements and guidance is needed in organizations engaged in professional testing. Therefore, **the need remains to use CMMI V2 and TMMi in a synergic way**.

At the same time, in CMMI V2 testing-related processes are not mentioned on Level 4 and Level 5. TMMi makes it possible to improve the testing processes above Level 3, reaching maturity levels 4 and 5. This is another advantage of using TMMi.

5 Possible TMMi Changes Recommended for Further Study

In this chapter we list some recommendations regarding the changes that, in our opinion, could be or should be studied in detail at a later stage in the context of TMMi 2.0. It is worth mentioning that CMMI is one of the candidate inputs for a possible TMMi V2.0. Other input must be considered as well (e.g., coming from the Agile community and ISTQB community etc.). One potential benefits of unifying (or, at least, bringing closer) CMMI V2 and TMMi structures is to make possible assessing the two models together.

Also, an organization using both CMMI and TMMi would save effort in implementation and

institutionalization of the models if they would have similar structure. In Table 5 we included a list of CMMI V2 changes considered important, together with an the result of our analysis on whether that a change would have an impact on TMMi, a short comment and the element of TMMi model which would be impacted by that change.

	CMMI 2 update	Impact on TMMi?	Comment	Category
	Structural updates			
1	Level 1 Practices introduced for all processes.	Yes	The entire concept of starting every practice are at Level 1 is a good approach.	Model
2	GG/GP are now Building and Sustaining Capability practices (GOV and II)	Yes	Check whether to get rid of GG/GP altogether in TMMi or also replace them	Model
3	Goals are replaced by "Intent and Value" of the Practice Area.	Yes	Would require complete re-writing. But would result in ease to use (as it focuses on meeting the intent of the practice).	Model
4	Adding the term of Capability areas (There are 10 capability areas, and each capability area includes several Practices areas) .Changing the term name PA - Process Area to PA - Practices Area. Each organization could diagnose what are their objectives and select the capability areas to improve, which meet the requirements of small, light, flexible and swift to pick the areas to improve.	Maybe	This would change the TMMi from staged to continuous. Not a priority.	Model
5	No distinction between GP and SP	Yes	This would change the structure of TMMi. Not a priority.	Model
6	Verification and Validation are merged to one PA: VV	Maybe	Some description in TMMi connected to CMMI support should be updated	Model
7	Some PAs renamed, some regrouped.	Maybe	Some description in TMMi connected to CMMI support should be updated. Eg: PMC->MC, PP->PLAN, OPD->PAD, OPF->PCM, RSKM->RSK MA is now MPM (Managing performance and management), PPQA is now including QA and testing activities.	Model
8	Estimation is now a separate PA.	Yes	Project Planning and Project monitoring and control are referenced in TMMi as helping to implement some planning- and monitoring-related practices. Estimation is within Planning in the actual version; in V2 should be a separate PA. No major changes in its practices, just dealt with separately.	model

	CMMI 2 update	Impact on TMMi?	Comment	Category
9	IPM split to PLAN and MC	Maybe	Some description in TMMi connected to CMMI support should be updated.	Model
	Business value, language			
10	Performance practices for benchmarking / ROI. Beneficial To prove the organization improved and institutionalized, a quantitative data of proof is required when submit the appraisal data.	Maybe	Might be interesting to drive ROI discussions for TMMi. This is a good and very convincing practice; will prove the benefits of the improvement with convincing evidence of tangible data. The difficulty might be in how to do the measurement, since it needs measurement capability of customer/external consultants or tools etc. Another issue might be confidentiality problem.	Model
11	Non-technical language. The whole framework was re-written using 3500 Frequency conversion words and a more user friendly English expression style.	Maybe	Might be interesting to make TMMi more accessible. Not a first priority.	Model
12	Emphasizing business objectives driving improvements and adding statement of the value of process improvements with each PA. Helps communicating with stakeholders on the improvement benefits of each PA.	Yes	Might be a good practice to consider in TMMi context, since testing stakeholders always ask what are the values for a certain PA or improvements practices.	Model
13	Adoption guidance	Yes	Crucial step to drive adoption of TMMi for a multi-level journey, should reuse	Guidance to implementation
14	The model is no longer accessible for free; there are license fees for 1,2… more users, and for different periods of time. Besides the .pdf, there is a Model Viewer also, that is quicker than scrolling up and down (but it needs some knowledge to use it).	Maybe	Our aim is to keep TMMi accessible for free. A Model Viewer tool would be nice to have.	Model, business construction, appraisals

Table 5.: Impact of CMMI V2 changes on TMMi

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7 Appendix

In this part we briefly present an approach that might be investigated as a possible step towards integration of TMMi and CMMI V2.0. This approach is a high- level one, based on the opinion formulated by the first author of this publication and does not yet reflect a common view nor a consensus within the TMMi community.

In our opinion, a feasible approach of integrating CMMI V2 and TMMi would be the creation of a **Customized View** of CMMI V2 for organizations that use TMMi (similar to what has been defined up till now for Safety or Security domains).

With a relatively low effort investment this could support organizations in integrating testing practices into their CMMI V2-conform Quality System. There could one single predefined view (called “CMMI for Development with Detailed Testing” or “CMMI for Development with TMMi”), or multiple views, grouping Process Areas by Capability Levels (“CMMI for Development L2 with TMMi”, “CMMI for Development L3 with TMMi” etc.)

A systematic analysis would be required to define the structure of such a customized view – which is out of the goal of this paper.

However, a simple approach would be to keep all Core Practice Areas of CMMI V2 and add all TMMi Practice Areas. This is presented in Figure 4.

	CMMI Development with TMMi					
	Practice Areas	Level 1	Level 2	Level 3	Level 4	Level 5
EST	Estimating	1	2	3		
PLA	Planing	1	2	3	4	
MC	Monitor and Control	1	2	3		
SAM	Supplier Agreement Management	1	2	3	4	
CAR	Causal Analysis and Resolution	1	2	3	4	5
DAR	Decision Analysis and Resolution	1	2	3		
CM	Configuration Management	1	2			
MPM	Managing Performance and Measurement	1	2	3	4	5
PCM	Process Management	1	2	3	4	
PAD	Process Asset Development	1	2	3		
RDN	Requirements Development and Management	1	2	3		
PQA	Process Quality Assurance	1	2	3		
VV	Verification and Validation	1	2	3		
PR	Peer Reviews	1	2	3		
TMMi	2.1 Test Policy and Strategy	1	2			
	2.2. Test Planning	1	2			
	2.3 Test Monitoring and Control	1	2			
	2.4 Test Design and Execution	1	2			
	2.5 Test Environment	1	2			
	3.1 Test Organization	1	2	3		
	3.2 Test Training Program	1	2	3		
	3.3 Test Lifecycle and Integration	1	2	3		
	3.4 Non-Functional Testing	1	2	3		
	3.5 Peer Review	1	2	3		
	4.1 Test Measurement	1	2	3	4	
	4.2 Product Quality Evaluation	1	2	3	4	
	4.3 Advanced Peer Review	1	2	3	4	
	5.1 Defect Prevention	1	2	3	4	5
	5.2 Quality Control	1	2	3	4	5
	5.3 Test Process Optimization	1	2	3	4	5
RSK	Risk and Opportunity Management	1	2	3		
OT	Organizational Taining	1	2	3		
GOV	Govermance	1	2	3	4	
=	Imlementation Infrastructure	1	2	3		

Figure 4. : A possible customized view: "CMMI for Development with TMMi"

In the above possible customized view we marked with a green background the Practice Areas coming from TMMi. We used red fonts to mark Practice Areas that would be, probably , removed, as the TMMi Practice Areas contain more detail related to testing than these.

Of course, synchronization must be done. For instance, converting the Specific Goals and Specific Practices to Practices; Generic Goals and Generic Practices need to be mapped to GOV an II Practice areas. And, of course, it would be a matter of decision of how much from the Process Management, Project Management and Support Practice Areas from CMMI V2 one would like to include with this predefined view.

TMMi in its actual version [13] explicitly states: "Although TMMi can be used in isolation, it is also positioned as a complementary model to the CMMI. As a result in many cases a given TMMi level needs specific support from process areas at its corresponding CMMI level or from higher CMMI levels. Process areas and practices that are elaborated within the CMMI generally are not repeated within TMMi; they are only referenced." Tables summarize the CMMI process areas that compliment and/or overlap with the TMMi process areas.

[13] https://tmmi.org/tm6/wp-content/uploads/2018/11/TMMi-Framework-R1-2.pdf, chapter 3.5.