

Capability Maturity Model Integration

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Introduction

The Capability Maturity Model Integration (CMMI), as defined by CMMI institute, is “a capability improvement model that can be adapted to solve any performance issue at any level of the organization in any industry” [1]. This model helps the organization find problems, solve them and therefore improve their performance. For example, CMMI can be used to improve processes for developing software in an organization. A process can be the management of the product development. The CMMI model follows different levels such as capability levels or maturity levels that will be detailed more in other sections of this paper.

This paper will provide an understanding of CMMI in general, its origin and evolution in section one, CMMI five maturity levels in section two, level 2 key processes in section three, the comparison between CMMI and Information Technology Infrastructure Library (ITIL) in section four, CMMI users in section five, return on investment for processing improvement in section six, application of CMMI concepts in agile environments in section seven and last Bibliography of this term paper.

I. CMMI origin and evolution

CMMI originated in software engineering at Carnegie Mellon University and was developed by the CMMI project, which consisted of a group from industry, government (i.e. US Department of Defense) and the software engineering institute (SEI). The current CMMI version 1.3 was developed in 2006. CMMI precedes the capability maturity model CMM [2] also developed at Carnegie Mellon in 1990, a model mainly used to improve software development processes in an organization.

The development of CMMI was formed to mitigate challenges faced by organizations that were using multiple CMMs (E.g. limitations of key process areas (KPAs) in CMM). Another reason was to integrate and standardize the separate models on CMM. Though CMMI did not replace CMM, the latter is still applicable. CMMI was initially a combination of three source models that were successful in the improvement of processes in an organization. These models are the Capability Maturity Model for Software (SW-CMM), the Systems Engineering Capability Model (SECM), and the Integrated Product Development Capability Maturity Model (IPD-CMM).

The first CMMI model, version 1.02 was released in 2000 to help organizations improve their services, and then version 1.1 and 1.2 were released after two and six years, from 2000, respectively. This version 1.2 changed the name later to CMMI for development, version 1.2. After one year, CMMI for Acquisition model version 1.2 was released. And again, two years later, CMMI for services version 1.2 was released. All these models lead to only three version 1.3 models: CMMI for development (CMMI-DEV), CMMI for Acquisition (CMMI-ACQ) and CMMI for services (CMMI-SVC).

The CMMI-DEV provides guidance for applying CMMI best practices for developing quality products and services. I think most of these products are successfully implemented because they meet the needs of customers and end users. CMMI-ACQ provides a comprehensive set of best practices for acquiring

products and services. CMMI-SVC provides a comprehensive set of best practices for providing services [6] [7] [8].

In brief, CMMI is a model that provides guidance for developing or improving processes that meet the business goals of an organization.

II. CMMI five maturity levels

As we have seen in the above sections, we have three CMMI models: CMMI-DEV, CMMI-ACQ, and CMMI-SVC. Apart from their objectives, they do not differ from their maturity levels. Per CMMI institute, levels are used in CMMI solutions to describe evolutionary paths recommended for organizations that wish to improve their processes used to develop, acquire and deliver products and services [2]. The improvement of those organizations is shown by CMMI using levels.

In CMMI, there exist two types of levels supported: Maturity levels and capability levels. Maturity levels provide a staging of processes for improvement across an organization from maturity level 1 to maturity level 5 [3]. Each level is a group of process areas (i.e. practices that when implemented satisfies a set of goals and thus making an improvement in a specific area in an organization. e.g. project planning). We will talk again about level 2 process areas in section three of this paper. Capability levels enable your organization to focus its process improvement efforts process area by process area from capability level 0 to capability level 3. Due to the scope of this paper, we will focus on maturity levels.

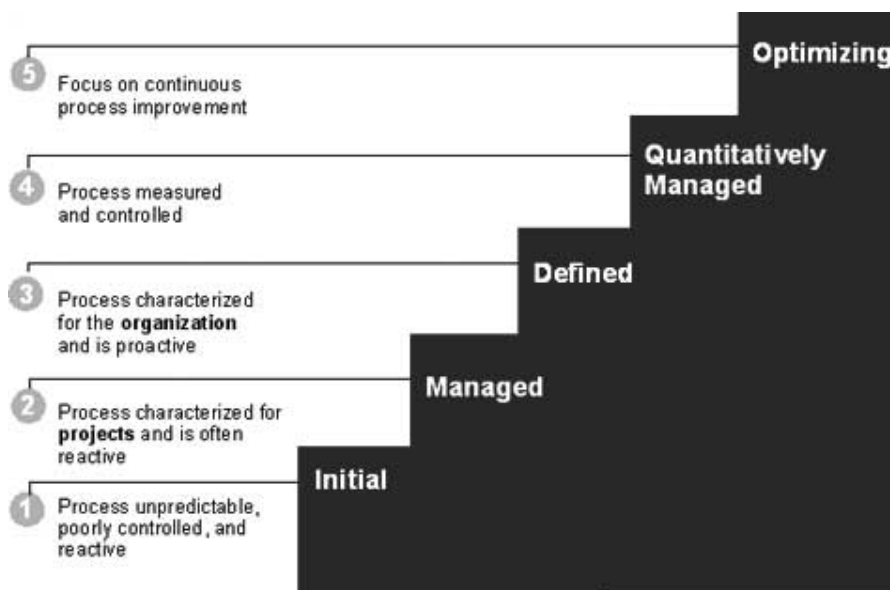


Figure 1: CMMI maturity levels _ staged representation

An organization reaches a particular level after satisfying all the goals of the process areas targeted for improvement. However, If a process meets all criteria for a level (e.g. level 2), and some criteria for an upper level (level 3), that process will still be considered as a level 2 process. In addition to that, each level builds on the previous level.

Maturity levels are explained in the following section, in much more detail:

1. **Initial**

Level 1 processes are described as chaotic, unordered and undocumented. For example, if we are an organization, and we try to develop an application, we are at level 1. This application is in a state of dynamic change due to an unstable environment in that organization. For example, this case can be mostly found in startups which rely on a single person to develop software following unproven processes.

2. **Managed**

Level 2 processes are repeatable and might lead to consistent results. Organizations at level 2 employ skilled people, and processes are planned and executed in an ordered manner. Those organization's projects are well-documented, existing processes are maintained during times of stress. For example, if an organization successfully implemented a project, they might want to select specific processes that lead to that project's success and then repeat them on projects with similar applications.

3. **Defined**

At this level, standard, well-defined and documented processes are established. All these processes are improved over time. This level differentiates itself from level 2 by the scope of standards, process descriptions and procedures [6]. In level 2, this scope can be different from one project to another. Whereas, in level 3, that scope follows the set of that organization's standard to suit a particular project.

4. **Quantitatively Managed**

Quantitative objectives are collected and analyzed based on the customers' needs, end users, organization, and process implementers. This analysis leads to quality and process performance results used in the management of projects. The main difference with level 3 is that the analysis information can be adopted in different projects where predictability of process performance is determined.

5. **Optimizing**

At level 5, the organization focus on continuous process improvement which is based on the analysis and quantitative understanding of its business objectives and performance needs [6]. Level 5 organizations focus more on the overall management and improvement of organizational performance based on results from different projects. This is different from level 4 because organizations focus more on understanding and controlling quality and performance. Few companies in the world have reached this maturity level [2].

III. Level 2 Key process areas

As defined in the first section, process areas are practices that when implemented satisfies a set of goals and thus making an improvement in a specific area in an organization. Process areas are grouped by maturity level indicating which process areas to implement to achieve each maturity level. An organization will move to another level after achieving all the goals of all process areas in that level. However, process areas can interact and have an effect on others regardless of their group.

Level 2 key process areas can be different from one model to another one among the three CMMI models: CMMI-DEV, CMMI-ACQ, and CMMI-SVC. Refer to the following table for such differences [6] [7] [8]:

CMMI for development	CMMI for Acquisition	CMMI for services
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• CM - Configuration Management • MA - Measurement and Analysis • PMC - Project Monitoring and Control • PP - Project Planning • PPQA - Process and Product Quality Assurance • REQM - Requirements Management • SAM - Supplier Agreement Management	• AM - Agreement Management • ARD - Acquisition Requirements Development • CM - Configuration Management • MA - Measurement and Analysis • PMC - Project Monitoring and Control • PP - Project Planning • PPQA - Process and Product Quality Assurance • REQM - Requirements Management • SSAD - Solicitation and Supplier Agreement Development	• CM - Configuration Management • MA - Measurement and Analysis • PPQA - Process and Product Quality Assurance • REQM - Requirements Management • SAM - Supplier Agreement Management • SD - Service Delivery • WMC - Work Monitoring and Control • WP - Work Planning
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Table 1: Level 2 key process areas for CCMI-DEV, CMMI-ACQ and CMMI-SVC

Level 2 KPAs can be classified into the following categories (i.e. for three different models): project and work management, support, acquisition engineering. Process areas in project and management category cover activities related to planning, monitoring, and controlling the project. Process areas in support category cover the activities that support product development and maintenance. And, those in acquisition engineering covers activities related to how to acquire quality products and services.

The following section provides explanations for each process area from Table 1. Refer to this table to be able to match a process area to a CMMI model.

As defined in CMMI model papers [6][7][8][9],

- CM - Configuration Management: is a support process area used to establish and maintain the integrity of work products using configuration identification, configuration control, configuration status accounting, and configuration audits.
- MA - Measurement and Analysis: is a support process area used to develop and sustain a measurement capability used to support management information needs.
- PMC - Project Monitoring and Control / WMC – Work Monitoring and Control: is a project and work management process area used to provide an understanding of the project/work's progress so that appropriate corrective actions can be taken when the project/work's performance deviates significantly from the plan.
- PP - Project Planning / WP – Work Planning (for CMMI-SVC): is a project management process area used to establish and maintain plans that define project/work activities.

- PPQA - Process and Product Quality Assurance: is a support process area used to provide staff and management with objective insight into processes and associated work products.
- REQM - Requirements Management: is a project management process area used to manage requirements of the project's products and product components and to ensure alignment between those requirements and the project plans and work products.
- SAM - Supplier Agreement Management: is a project (and work) management process used to manage the acquisition of products from suppliers.
- AM - Agreement Management: is a project and work management process area used to ensure that the supplier and the acquirer perform according to the terms of the supplier agreement.
- ARD - Acquisition Requirements Development: is an acquisition engineering process area used to elicit, develop, and analyze customer and contractual requirements.
- SSAD - Solicitation and Supplier Agreement Development: is a project and work management process area used to prepare a solicitation package, select one or more suppliers to deliver the product or service and establish and maintain the supplier agreement.
- SD - Service Delivery: is a service establishment and the delivery process area which is used to analyze, design, develop, integrate, verify, and validate service systems, including service system components, to satisfy existing or anticipated service agreements.

IV. Capability Maturity Model Integration and IT Infrastructure Library

ITIL is a model that focuses on IT-related issues. ITIL is said to be a non-proprietary tool that encourages the private sector to develop services and products such as training, consultancy, and tools to support ITIL. ITIL was developed by the United Kingdom's Office of Governmental Commerce (OGC) in 1986 and has become the most widely used approach to IT Service Management in the world [10].

Similarity: CMMI and ITIL improve the software development process and software quality and reduce the cost of quality. For example, in software development, CMMI helps an organization to understand what process is better.

Differences between CMMI and ITIL:

CMMI	ITIL
CMMI is a model used to solve any performance issue or improve the processes of software development within an organization.	ITIL is a set of best practices that might be used by an IT organization to control and manage all aspects of IT related operations or issues.
CMMI was developed by SEI at Carnegie Mellon University as precedence to CMM which was developed earlier in 1990.	ITIL was developed by OGC in 1986 to provide guidance for service management.
CMMI focuses on software development, integration, deployment and maintenance	ITIL focuses on IT operations and services
Most important for software development processes	Most important for operations and IT infrastructure, particularly IT services such as configurations, security, troubleshooting...

CMMI focuses on the total-system problem [21].	ITIL focuses on IT-related issues
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Table 2: Differences between CMMI vs ITIL

V. CMMI users

The CMMI institute statistics [17] show that more organizations prefer CMMI-DEV v1.3 staged representation and a small number prefer to adopt CMMI-DEV continuous representation in various countries. These statistics also show that almost all organizations at level 5 use a staged representation. This difference is the motivation to analyze both staged and continuous representations in CMMI.

Two organizations from the United States will be used as an example in this section. First, Armedia, LLC is a technology firm focusing on information and content management solutions [18]. it uses a continuous representation. 1901 Group, LLC is a provider of IT services for the public and private sector [20]; it prefers to use a staged representation. This section shows some understanding of the two terms and analysis on why more companies adopt staged and other companies, continuous. The statistics show that more IT industries use a staged representation.

Table 3 gives some understanding of both representations:

Staged representation	Continuous representation
1.1. A staged representation uses maturity levels to measure process improvement. Those maturity levels apply to an organization's overall maturity.	2.1. A continuous representation uses capability levels to measure process improvement. Those capability levels apply to an organization's process improvement achievement for each process area [19].
1.2. Uses predefined and proven path with case study which performance in time management.	2.2. Flexible in the prioritization of process improvements but requires understanding of Process areas relationships.
1.3 Overall results are summarized in a maturity level	2.3. Improvement of process areas or results can occur at different times.

Table 3: staged vs continuous representations

Both representations are said to be nearly identical. The question is why one organization should use a staged representation or a continuous representation.

Why a staged representation?

- Some organizations willing to transition from Software CMM (SW-CMM) to CMMI uses staged representation which is easy for them.
- An Organization with business objectives to do business with the government organizations that require a maturity level for their procurements.

- Organizations which are not familiar with dependencies among process areas.

Why a continuous representation?

- Small companies might choose a continuous representation because it focuses more on specific process areas that on how to reach different upper levels (*Refer to table 2, 2.1*).
- It is also easy for organizations to focus on specific improvements that are needed the most by prioritizing (*Refer to table 2, 2.2*).
- Other organizations choose this representation because it is easier for them because they already understand the process area relationships and identified specific improvements needed in the organization.

Now using our example, organizations to prove some statements, 1901 Group, an IT service provider has contracts with the government [20], this might confirm why it uses a staged representation. Armedia that provides software development services uses a continuous representation. This might probably be because it focuses on specific areas to improve than the overall organization.

In brief, both representations use the same content but are organized differently. Any organization might choose one representation based on the following its objectives, legacy... For example business objectives, like willing to do business with the government organizations as described in the above section. One other point that I did not have a chance to analyze because of limited time is to think about is why we do have almost no organizations using CMMI-DEV v1.3 continuous representation, at Maturity Level 4 and 5, in 2015 in the United States? I think it might be because continuous representation takes longer to reach levels than staged representation.

VI. Return on investment for process improvement

Return on investment is an important measurement needed by organizations to measure their process improvement. ROI is also needed in the communication of the organization's executives or decision makers. The analysis in the paper "Demonstrating the impact and benefits of CMMI" shows that measures of performance that can be used to demonstrate the impact of in CMMI-based process improvement are: cost, schedule, quality, customer satisfaction and return on investment [21].

The statistics show that the cost can be reduced when CMMI-based process improvement is adopted. For example, there was a 33 % decrease in the average cost to fix a defect in Boeing, Australia. For schedule measurement, the time required to do the work can also reduce which can, for example, increase the software productivity. For quality measurement, adopting CMMI can reduce the number of defects in the product. Customer satisfaction is also a measure of the benefits of process improvement. An example is an organization, Northrop Grumman IT1, which received more than 98 % of possible customer award fees [21].

The costs and benefits can be combined to calculate ROI. For example, ROI can measure how many defects were avoided per day, the quality of a product... For an organization to keep on improving its processes in a measured manner, ROI should be tracked every 6 to 1 year.

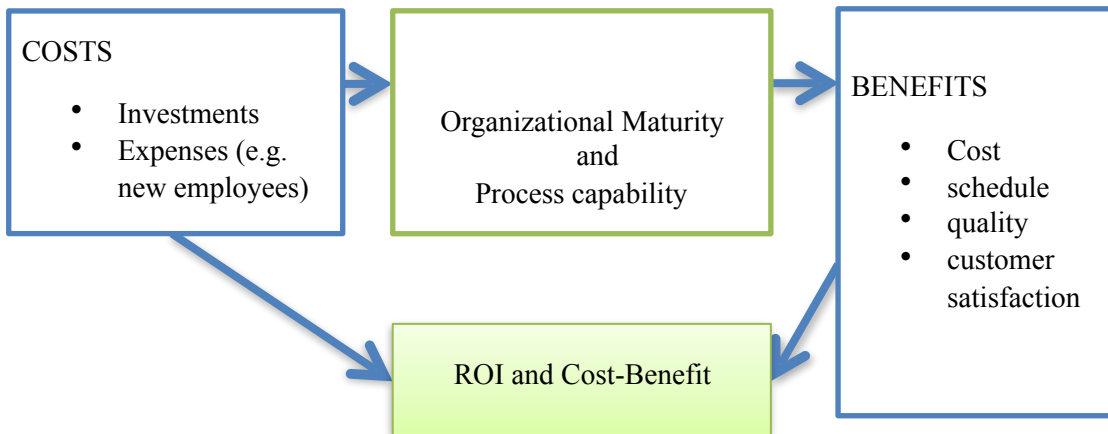


Figure 2: Measurements of performance

VI. Applying CMMI concepts in agile environments

CMMI, as described by Hillel Glazer in “Agile CMMI” paper, is a model that helps an organization ask the right questions, thus leading to the better decisions in that organization. (E.g. do you have all requirements of your client?). As he mentioned, these decisions can help an organization adopting agile because the latter cannot ask questions like CCMI. This is true since agile is a set of practices and processes used to develop, for example, a software product, a system...

Agile uses some practices such as scrum and extreme programming. These practices enable agile to be more powerful, even when it is applied in other models such as CMMI. Now that CMMI includes some agile practices, it became easier to assess an organization’s performance.

Let’s now discuss the other way of applying CMMI concepts in agile environments. I think the concept of maturity levels in CMMI can fit well in agile environments if each process is mapped with a sprint in scrum framework. However, processes at each maturity level might take longer to finish which is not the objective of Scrum. (I.e. its objective is to produce a release document or a product’s version after each sprint). I think there would also be more repeatability since agile sprints have the same execution steps (i.e. in agile, every sprint must have requirements gathering, analysis, design, coding, testing).

In brief, agile and CMMI can effectively work together. However, adopting some CMMI methods like maturity levels or process areas might take longer in agile development even for small sprint (i.e. lasting 2 weeks). That would probably require companies to first be more familiar with CMMI.

VII. Conclusion

This document provides a more detailed explanation on the CMMI origin, evolution, maturity levels, and CMMI users, ITIL, return on investment for process improvement and the application of CMMI concepts in agile environments. CMMI can be adopted by organizations that wish to maintain quality in projects

which cost saving in terms of lesser effort due to fewer defects and less rework and thus improve productivity. It can be implemented together with other methodologies such as agile.

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