CAPABILITY MATURITY MODEL INTEGRATION

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Abstract: *In this paper we present an introduction to, and an overview to the CMMI process model, that appeared from the need to address generic, company-wide, organizational issues for a wider range of activity domains, providing a flexible framework that allows further 'plug-in' extensions to be added.*

Key words: *process; capability maturity model; process areas*

Introduction

In an attempt to improve the way organizations and companies organize and do business, many models, standards and methodologies have been developed. Unfortunately, the majority of these models are meant to improve specific activities for specific organizations only and do not take a systematic approach to the general problems that most organizations are facing. Such models have been created for software developing companies – Software Engineering Institute's (SEI) Capability Maturity Model for Software (SW-CMM) focuses on software engineering organizations; others concentrate on systems engineering – Electronic Industries Alliance's (EIA) Systems Engineering Capability Model (SECM). As mentioned earlier, those models can improve specific activities and are less useful addressing organization-wide issues.

In an attempt to minimize the aforementioned problems, CMMI comes in with general guidelines and models that transcend disciplines, addressing the entire product life cycle from conception, development, delivery and maintenance. Moreover, the model is conceived as a core, onto which further extensions can be added.

Process Models

There are several dimensions an organization can focus on to improve its business. Figure 1 illustrates the three critical dimensions that organizations typically focus on: people, procedures and methods, tools and equipment.

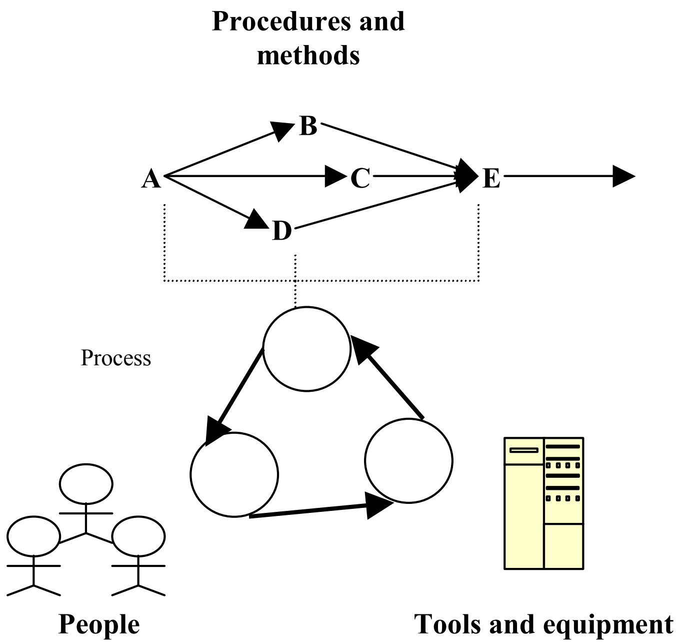

Figure 1. The Three Critical Dimensions

The three critical dimensions are held together through the processes used in the organization.

A process is defined by IEEE as "a sequence of steps performed for a given purpose". As the CMMI model puts it, evaluating the efficiency of an organization can be reduced to evaluating the efficiency of its processes, and introduces as a measure of an organization's efficiency the maturity levels.

In case of immature organizations, processes are improvised by practitioners, the process descriptions are not rigorously followed nor enforced and the organization performance is highly dependent on current practitioners. The mature organizations' processes have descriptions consistent with the way the work actually gets done; they are defined, documented and continuously improved. Mature organizations' processes are visibly supported by managers, are well controlled and there is constructive use of product and process measurement, and are institutionalized, meaning that the organization builds an infrastructure that contains effective, usable and consistently applied processes.

A process model is a structured collection of practices that describe the ***characteristics*** of effective processes. It provides its users with a common language and a shared vision.

Capability Maturity Models

Capability maturity models (CMMs) focus on improving processes in an organization. They contain the essential elements of effective processes for one or more disciplines and describe an evolutionary improvement path from ad hoc, immature processes to disciplined, mature processes with improved quality and effectiveness.

The CMM Integration project was formed in order to outrun the problem of using multiple CMMs. Three source models were combined:

1. The Capability Maturity Model for Software (SW-CMM) v2.0
2. The Systems Engineering Capability Model (SECM)
3. The Integrated Product Development Capability Maturity Model (IPD-CMM)

The intent of CMMI is to provide a CMM that covers product and service development and maintenance but also provides an extensible framework so that new bodies of knowledge can be added. Currently, four bodies of knowledge are available when planning process improvement using CMMI:

- Systems engineering
- Software engineering
- Integrated product and process development
- Supplier sourcing

Disciplines, which are the discussed bodies of knowledge, are addressed by the process areas associated with them and by model components called discipline amplifications. A process area is a cluster of related best practices in an area that, when implemented collectively, satisfies a set of goals considered important for making significant improvement in that area.

For systems engineering, the CMMI identifies 22 theoretical process areas:

1. Causal Analysis and Resolution
2. Configuration Management
3. Decision Analysis and Resolution
4. Integrated Project Management (the first two specific goals)
5. Measurement and Analysis
6. Organizational Innovation and Deployment
7. Organizational Process Definition
8. Organizational Process Focus
9. Organizational Process Performance
10. Organizational Training
11. Product Integration
12. Project Monitoring and Control
13. Project Planning
14. Process and Product Quality Assurance
15. Quantitative Project Management
16. Requirements Development
17. Requirements Management
18. Risk Management
19. Supplier Agreement Management
20. Technical Solution
21. Validation
22. Verification

In the case of software engineering organizations, the process areas listed for systems engineering remain the same. The only difference in the CMMI model is that the discipline amplifications for software engineering receive special emphasis.

In case of improving the integrated product and process development processes, there are two additional process areas as in the systems engineering discipline and additional best practices in the Integrated Project Management process area. These two additional process areas are:

- Integrated Teaming
- Organizational Environment for Integration

In case of improving the source selection processes, there are the same process areas as in systems engineering with one additional process area, *Integrated Supplier Management*. The discipline amplifications for supplier sourcing receive special emphasis.

In case of improving multiple disciplines, the model architect has to choose from the process areas listed under all of the relevant disciplines and pay attention to all of the discipline amplifications for those disciplines.

CMM Approaches: Representations

The CMMI model provides its users two approaches to process improvement; these are the so-called "model representations", which can be thought of as two different views of the same data, which is the CMMI model.

The **continuous representation** offers a detailed image of an organization's processes. It will allow an organization to evaluate process areas individually, and it is the representation commonly used in process improvement, because it allows identifying and focusing on trouble spots, and measuring improvement progress on a finer-grained scale.

For each process area, capability levels are used to measure the improvement path from an unperformed process to an optimizing process. Capability levels cannot be skipped, and are built one on top of another: the capability level X contains inherently the requirements of the capability level X-1. The first capability level, CL0 contains no requirements, but it is rather defined by the lack of any of the performance characteristics required at the first **appraisable** capability level. The last capability level, CL5 can be seen as an assurance for lasting, continuous self improvement in that specific process area. The CMMI's six capability levels are represented in Table 1.

Table 1. Capability Levels

Identifier	Capability Level
0	Incomplete
1	Performed
2	Managed
3	Defined
4	Quantitatively Managed
5	Optimizing

Using the continuous representation implies a good understanding of dependencies among the process areas, since the intrinsic interconnections between them might require a certain capability level for another process area before another reaches a targeted capability level. This representation organizes the process areas from a lucrative point of view in four basic categories:

- Support: contains processes that do not have an external / commercial output, but provide the foundation on which the rest of the organization can perform an efficient activity
- Engineering: contains processes that "do the work" - perform the actual work of the organization
- Project Management: contains processes that coordinate to efficiency the "actual work" of the organization
- Process Management: contains processes that set paths for the entire organization

Table 2 represents the process areas in the continuous representation.

Table 2. Continuous representation

Category	Process Area
Process Management	Organizational Process Focus (OPF) Organizational Process Definition (OPD) Organizational Training (OT) Organizational Process Performance (OPP) Organizational Innovation and Deployment (OID)
Project Management	Project Planning (PP) Project Monitoring and Control (PMC) Supplier Agreement Management (SAM) Integrated Project Management (IPM) Risk Management (RSKM) Integrated Teaming (IT) Integrated Supplier Management (ISM) Quantitative Project Management (QPM)
Engineering	Requirements Management (REQM) Requirements Development (RD) Technical Solution (TS) Product Integration (PI) Verification (VER) Validation (VAL)
Support	Configuration Management (CM) Process and Product Quality Assurance (PPQA) Measurement and Analysis (MA) Decision Analysis and Resolution (DAR) Organizational Environment for Integration (OEI) Causal Analysis and Resolution (CAR)

The **staged representation** offers a view at the organization level, providing a measure for the entire organization. It is less detailed than the continuous representation, but it provides a higher-level view of the entire organization, and a simple, straightforward, easily understandable label, with more direct commercial / business implications. The staged representation will provide as a standardized measure the entire organization's **maturity level**.

Just as processes capability levels, the maturity levels are built one on top of each other, so a level cannot be 'skipped', and a superior maturity level has, intrinsically, the maturity requirements of the inferior maturity levels. As a difference, the first level in the staged representation is maturity level 1 – ML1, but the concept behind the first level stays the same: this first level is rather characterized by a lack of complying to the requirements of the first **appraisable** maturity level. The maturity levels are represented in Table 3.

Table 3. Maturity Levels

Identifier	Maturity Level	Meaning
1	Initial	"Do the work"
2	Managed	
3	Defined	
4	Quantitatively Managed	
5	Optimizing	

There is a strong relationship between the two representations, not only in terms of levels naming. Any maturity level implies that in the continuous representation a group of process areas have reached certain capability levels

The staged representation offers a roadmap to efficiently focus on improving process and process areas, with milestones for bringing the entire organization in a coherent and uniform way from the initial level to the optimizing level, ensuring a robust incremental improvement. Achieving a maturity level sets a solid basis for the entire organization improvement towards the next maturity level.

The staged representation is also seen as a good choice when starting a process improvement initiative lacking precise directions towards the areas that need improvement. More than a decade of research and experience in the software community has shown that this is the enduring path to be followed when improving organization-wide. Table 4 represents the process areas in the staged representation.

Table 4. Staged representation

Level	Focus	Process Areas
Optimizing	Continuous Process Improvement	Organizational Innovation and Deployment (OID) Causal Analysis and Resolution (CAR)
Quantitatively Managed	Quantitative Management	Organizational Process Performance (OPP) Quantitative Project Management (QPM)
Defined	Process Standardization	Requirements Development (RD) Technical Solution (TS) Product Integration (PI) Verification (VER) Validation (VAL) Organizational Process Focus (OPF) Organizational Process Definition (OPD) Organizational Training (OT) Integrated Project Management (IPM) Risk Management (RSKM) Integrated Teaming (IT) Integrated Supplier Management (ISM) Decision Analysis and Resolution (DAR) Organizational Environment for Integration (OEI)
Managed	Basic Project Management	Requirements Management (REQM)

		Project Planning (PP) Project Monitoring and Control (PMC) Supplier Agreement Management (SAM) Measurement and Analysis (MA) Process and Product Quality Assurance (PPQA) Configuration Management (CM)
Initial		

Conclusions

CMMI provides an interconnected and hence stable model, with more detailed coverage of the product life cycle than other process-improvement alternative products. CMMI assimilates the experience of an entire community, and many lessons learned during the development, maintenance, and usage of the source models from which it was developed, addressing some problems found, for example, in both the Software CMM and the SECM.

CMMI joins software engineering and systems engineering into product engineering, therefore providing organizations with a powerful integrated toolset. It promotes collaboration between systems engineering and software engineering, helping organizations focus on the end product and its associated processes. It allows for flexibility in implementing the model to better suit an organization's business objectives, allowing at the same time for common terminology, architecture, and appraisal methods.

Even though the initial focus of CMMI was on product and service engineering, CMMI was designed for other disciplines as well, thereby supporting enterprise-wide process improvement.

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