

Capability Maturity Model Integration (CMMI)

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Abstract—CMMI (Capability Maturity Model Integration) is a process improvement maturity model for the development of products and services. It consists of best practices that address development and maintenance activities that cover the product lifecycle from inception through delivery and maintenance. The purpose of CMMI for software development is to help organizations improve their development and maintenance processes for both products and services. In this paper, we have tried to focus on the importance of process improvement in a software organization by discussing the various aspects of Capability Maturity Model's different process areas.

Index Terms—CMMI, models, process, levels.

1 INTRODUCTION

SOFTWARE process is the set of tools, methods, and practices we use to produce a software product. The objectives of software process management are to produce products according to plan while simultaneously improving organization's capability to produce better products. In launching a process improvement program, we should first consider the characteristics of a truly effective software process. Fundamentally, it must be predictable – cost estimates and scheduling commitments must be met with reasonable consistency, and the resulting products should generally meet users' functional and quality expectations. Quality software project management is based upon the inter-laced bodies of knowledge from three sources: Software Engineering (ACM, IEEE), Project Management (PMI), and Quality (ASQ). The Software Engineering Institute (SEI) at Carnegie Mellon University incorporates all three. The Capability Maturity Model (CMM), a publicly available product, serves as a software process framework that is based on actual practices, that reflects the best of the state of practice, and that reflects the needs of individuals performing software process improvement and software process appraisals.

In this paper we have organized part by part of CMMI framework in an easy way. We have described maturity levels, representations, process, goals, project planning, and risk management in a short and easy way. The CMMI provides a framework for organizing evolutionary steps into five maturity levels that lay successive foundations for continuous process improvement. A maturity level is a well-defined evolutionary plateau toward achieving a mature software process. Each maturity level comprises a set of

process goals that, when satisfied, stabilize an important component of the software process. Organizing the CMMI into the five levels: (1) Initial, (2) Managed, (3) Defined, (4) Quantitatively Managed and (5) Optimizing, prioritizes improvement actions for increasing software process maturity. Each maturity level is decomposed into several Process Areas (PA) that indicate where an organization should focus to improve its software process.

Process areas are sets of related practices expected to perform to attain the required goals of each process area. Each process area contains two types of goals that must be fulfilled: Specific Goals and Generic Goals. A process area is satisfied when company processes cover all of the generic and specific goals and practices for that process area.

A specific goal is specific to a given process area. A specific goal is to apply to a process area and address the unique characteristics that describe what must be implemented to satisfy the process area. Specific goals are required model components and are used in appraisals to help determine whether a process area is satisfied.

A generic goal is the same goal statement appears in multiple process areas. Each process area has only one generic goal. Achievement of a generic goal in a process area signifies improved control in planning and implementing the processes associated with that process area, thus indicating whether these processes are likely to be effective, repeatable, and lasting. Generic goals are required model components and are used in appraisals to determine whether a process area is satisfied.

The goal of CMMI is process improvement through Software Process Improvement (SPI) framework. CMMI defines processes and activities to implement in the project and the way to be carried out.

There are two different approaches for representations: Continuous representation and Staged representation in process improvement and appraisals. In Continuous representation there are six capability levels which correspond to a generic goal and a set of generic and specific practices. And in Staged representation there are five maturity levels which are applied to an organization's overall maturity.

There are five maturity levels, which allow a layer in the

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foundation. CMMI Level 1 is an ad hoc, uncontrolled and reactive manner by users. CMMI Level 2 is said to be a Managed level. It is said managed because requirements are fulfilled, processes are planned, performed, measured, and controlled. A traceable document is maintained to monitor requirement which may be new or changes to the existing. Project Planning defines a framework to develop software determining attributes, project life cycle, duration and cost. Project Monitoring and Control identifies the deviations from the project plan and control the progress of the project to produce timely. It also monitors project risks and data management. Measurement and Analysis is software processes in various projects for performance, which will be used for future improvement in both quality and productivity. The Supplier Agreement Management is structured identification of the effective supplier with purchases of tools. The Process and Product Quality Assurance is to ensure that the software is effective for services to reach the goal. The function of Configuration Management is to establish and maintain the integrity of the project's work and deliverables for controlled changes. CMMI Level 3 has eleven process areas. Firstly an analysis is done and takes decision, then the project is integrated into several parts to perform every task simultaneously. After that the organization defines the process and manages some training to focus over the process. Then the requirements are made and provided some Technical Solution under some risk. Finally validate the product to ensure the effectiveness and Verification process ensures compliance with its specified requirements. Quantitative Project Management and Organizational Process Performance are the process area involved in Level 4. Organizational Process Performance is to establish provide the process performance data, baselines and models. And Quantitative Project Management is to quantitatively manage the defined process to achieve the project's established quality and performance. Causal Analysis and Resolution and Organizational Innovation and Deployment are two process area of Level 5. Causal Analysis and Resolution is to identify causes of defects and actions to prevent. Organizational Innovation and Deployment are to plan the deployment areas, manage the deployment and measure improvement effects.

2 OVERVIEW

It is important to note that CMMI defines what processes and activities need to be implemented and not how these processes and activities are carried out. The goal of CMMI is process improvement and CMMI can be thought of as a Software Process Improvement, (SPI)framework. There are 3 areas addressed by CMMI, namely: CMMI Development, CMMI Services and CMMI Acquisition. CMMI for Development has 22 process areas that represent the core processes for software development. For each process area a list of practices (or capabilities) is given. The idea being that a software development organization improves their capability by implementing the practices. There are a number of levels of capability which are achieved by applying more

definition and control to the key development processes. The level of capability (of a given software development organization) can be assessed by an independent auditor, usually external.

3 CONTINUOUS AND STAGED REPRESENTATIONS

CMMI enables us to approach process improvement and appraisals using two different representations: Continuous and Staged. In continuous representation, capability levels, apply to an organization's process improvement achievement for each process area. There are six capability levels, numbered 0 through 5. Each capability level corresponds to a generic goal and a set of generic and specific practices. If continuous representation is chosen by an organization, it is expected that the model will do as Allows selecting the order of improvement that best meets the organization's business objectives and mitigates the organization's areas of risk. Enables comparisons across and among organizations on a process area by process area basis or by comparing results through the use of equivalent staging.

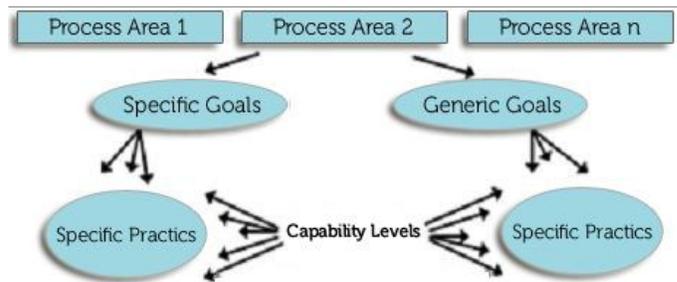


Fig. 1. CMMI Continuous Representation

Maturity levels, which belong to the staged representation, apply to an organization's overall maturity. There are five maturity levels, numbered 1 through 5. Each maturity level comprises a predefined set of process areas. If the staged representation is chosen by an organization, it is expected that the model will do as- Provide a proven sequence of improvements, beginning with basic management practices and progressing through a predefined and proven path of successive levels, each serving as a foundation for the next. Permit comparisons across and among organizations by the use of maturity levels. Provide a single rating that summarizes appraisal results and allows comparisons among organizations.



Fig. 2. CMMI Staged Representation

4 WHY DO WE NEED CMMI

CMMI is about improving performance through improving operational processes. In particular, it's improving processes associated with managing how organizations develop or acquire solution-based wares and define and deliver their services. The CMMI has provided significant value for many organizations that have used it as a guide for improving the way they do their engineering work. It has helped them to gain control over their processes – Management, Engineering and Supporting processes – to assure that those processes serve the needs of the organization. By following the guidance of the CMMI, Organization can put them on the road to more effective processes so can achieve more consistent success in engineering projects.

Successful process improvement initiatives must be driven by the business objectives of the organization. For any software development organization, the key factors for success should be delivering the product / project on time and within budget maintaining the quality and fulfilling the functional, non-functional requirements. CMMI covers all the process areas in such a way that ensures this. All the twenty two process areas can be grouped into four major categories: Process Management, Project Management, Engineering and Support.

5 CMMI MATURITY LEVEL

A maturity level is a well-defined evolutionary plateau toward achieving a mature software process. Each maturity level provides a layer in the foundation for continuous process improvement.

5.1 CMMI Level 1

It is characteristic of processes at this level that they are (typically) undocumented and in a state of dynamic change, tending to be driven in an ad hoc, uncontrolled and reactive manner by users or events. This provides a chaotic or unstable environment for the processes.

5.2 CMMI Level 2

CMMI Level 2 is the second of the five maturity levels in the staged representation of the CMMI. It's known as the managed level when the projects of an organization have ensured that requirements are managed and that processes are planned, performed, measured, and controlled, then that organization will be appraised as CMMI Level 2 or Managed level.

CMMI Level-2 has the following process areas to conform:

1. Requirements Management
2. Project Planning
3. Project Monitoring and Control
4. Measurement and Analysis
5. Supplier Agreement Management
6. Process and Product Quality Assurance
7. Configuration Management.

Each process area has one or more specific goals. Each specific goal has one or more specific practices. In CMMI Level-2, each process area has a single generic goal that contains-



Fig. 3. CMMI Level 2 Process areas

generic practices. Generic goal of CMMI Level 2 is institutionalize a Managed Process. Generic practices for this generic goal are Establish an Organizational Policy, Plan the Process, Provide Resources, Assign Responsibility, Train People, Manage Configurations, Identify and Involve Relevant Stakeholders, Monitor and Control the Process, Objectively Evaluate Adherence.

5.2.1 Requirements Management (REQM)

The policy of the Requirements Management is to manage and document the requirements and its traceability, where requirement can be new or changes to the existing, so as to monitor and control the impact on the projects plans and its dependencies. Specific Goal is to Manage Requirements. Specific Practices are Obtain an Understanding of Requirements, Obtain Commitment to Requirements, Manage Requirements Changes, Maintain Bidirectional Traceability of Requirements, Identify Inconsistencies between Project Work and Requirements.

5.2.2 Project Planning (PP)

The policy of the Project Planning is to define a framework for software development and software maintenance teams to develop their project plans to determine the duration, work efforts and resource efforts to identify the effective milestones/deliverables. Specific Goal is to Establish Estimates and Specific Practices are to Estimate the Scope of the Project, Establish Estimates of Work Product and Task Attributes, Define Project Life Cycle, Determine Estimates of Effort and Cost. Specific Goals is to develop a Project Plan and Specific Practices are establishing the Budget and Scheduling, Identifying Project Risks, Planning for Data Management, Planning for Project Resources, Planning for Needed Knowledge and Skills, Planning Stakeholder Involvement, Establishing the Project Plan. Specific Goal Obtains Commitment to the Plan. Specific Practices are Review Plans that affect the Project, Reconcile Work and Resource Levels, Obtain Plan Commitment.

5.2.3 Project Monitoring and Control (PMC)

The policy of Project Monitoring and Control is to quantitatively identify/monitor the deviations from the estimated

project plan and control the progress of the project to produce timely milestones/deliverables. Specific Goal is to Monitor Project against Plan and Specific Practices are to Monitor Project Planning Parameters, Monitor Commitments, Monitor Project Risks, Monitor Data Management, Monitor Stakeholder Involvement, Conduct Progress Reviews, Conduct Milestone Reviews. Specific Goal Manages Corrective Action to Closure and Specific Practices are Analyze Issues, Take Corrective Action, Manage Corrective Action.

5.2.4 Measurement and Analysis (MA)

The policy of Measurement and Analysis is to quantitatively measure the software engineering processes for various projects, to derive the progress indicators for the organization's performance, which will be used for future improvement in both quality and productivity. Specific Goal is to Align Measurement and Analysis Activities. Specific Practices are Establish Measurement Objectives, Specify Measures, Specify Data Collection and Storage Procedures, Specify Analysis Procedures. Specific Goal is to Provide Measurement Results and Specific Practices are to Collect Measurement Data, Analyze Measurement Data, Store Data and Results, Communicate Results.

5.2.5 Supplier Agreement Management (SAM)

The policy of Supplier Agreement Management is to manage and document the process of structured identification of the effective supplier with quantitative justification and enforce the agreement liability for required purchases of services and/or tools. Specific Goal is to Establish Supplier Agreements. Specific Practices are to Determine Acquisition Type, Select Suppliers, Establish Supplier Agreements. Specific Goal is to Satisfy Supplier Agreements and Specific Practices are to Execute the Supplier Agreement, Monitor Selected Supplier Processes, Evaluate Selected Supplier Work Products, Accept the Acquired Product, Transition Products.

5.2.6 Process and Product Quality Assurance (PPQA)

The policy of Process and Product Quality Assurance is to ensure that the organizations processes are implemented effectively and adhere to the quality standards defined for each processes. Specific goal is to evaluate processes and work products and specific practices are to objectively evaluate work products and services. Specific goal is to provide objective insight and specific practices involve communicating and ensuring resolution of noncompliance issues, establishing records.

5.2.7 Configuration Management (CM)

The policy of Configuration Management is to establish and maintain the integrity of the project's work and deliverables for controlled changes and rollback. Specific goal includes establishment of baselines and specific practices are identifying configuration items, establish a configuration management system, create or release baselines. Specific goal is to track and control changes and specific practices are to track change requests, control configuration items.

5.3 CMMI Level 3

These are process areas in CMMI Level 3.

1. Decision Analysis and Resolution
2. Integrated Project Management +IPPD
3. Organizational Process Definition +IPPD
4. Organizational Process Focus
5. Organizational Training
6. Product Integration
7. Requirements Development
8. Risk Management
9. Technical Solution
10. Validation
11. Verification.



Fig. 4. CMMI Level 3 Process areas

5.3.1 Decision Analysis and Resolution (DAR)

The policy of Decision Analysis and Resolution is to define structured and documented methodology for making decision using evaluation method for alternative solutions against the established criteria.

5.3.2 Integrated Project Management +IPPD (IPM)

The policy of the Integrated Project Management is to provide established and structured methodology for tailoring the organization's set of standard process to meet the customized SDLC requirement of the customer. Specific Goal is Using the Project's Defined Process and Specific Practices are to Establish the Project's Defined Process, Use Organizational Process Assets for Planning Project Activities, Establish the Project's Work Environment, Integrate Plans, Manage the Project Using the Integrated Plans, Contribute to the Organizational Process Assets. Specific Goal is to Coordinate and Collaborate with Relevant Stakeholders and Specific Practices are to Manage Stakeholder Involvement, Manage Dependencies, Resolve Coordination Issues.

5.3.3 Organizational Process Definition +IPPD (OPD)

The policy of the Organizational Process Definition is to establish a structured and consistent approach of process implementation. Specific Goal is Establishing Organization-

al Process Assets and Specific Practices are Establishing Standard Processes, Establishing Life-Cycle Model Descriptions, Establishing Tailoring Criteria and Guidelines, Establishing the Organization's Measurement Repository, Establishing the Organization's Process Asset Library.

5.3.4 Organizational Process Focus (OPF)

The policy of the Organizational Process Focus is to plan and implement organizational process improvement based on a thorough understanding of the current strengths and weaknesses of the organization's processes and process assets. Specific Goal is Determine Process Improvement Opportunities and Specific Practices are Establish Organizational Process Needs, Appraise the Organization's Processes, Identify the Organization's Process Improvements. Specific Goal is to Plan and Implement Process Improvement Activities and Specific Practices are to Establish Process Action Plans, Implement Process Action Plans. Specific Goal is to Deploy Organizational Process Assets and Incorporate Lessons Learned and Specific Practices are to Deploy Organizational Process Assets, Deploy Standard Processes, Monitor Implementation, Incorporate Process-Related Experiences into the Organizational Process Assets.

5.3.5 Organizational Training (OT)

The policy of the Organizational Training is to develop the skills and knowledge of people to enhance the productivity, resource usage and employee satisfaction.

5.3.6 Product Integration (PI)

The policy of the Product Integration is to produce simple and effective assembly of the product and its component to maintain the integrity and validity of the system, software and process requirements, to satisfy quick and easy deployment.

5.3.7 Requirements Development (RD)

The policy of Requirements Development is to establish and maintain the requirements of system, software and processes in more presentable and conceptually clear requirements without any ambiguity. It covers the specific goal and practices for elicitation and development of the requirements, identifying interrelations, validation of the requirements and also the analysis of the requirements.

5.3.8 Risk Management (RSKM)

The policy of Risk Management is to actively identify, analyze and mitigate the risks associated with requirements for system, software and processes and its impact on dependent software development life cycle phases. Specific Goal is to Prepare for Risk Management and Specific Practices are to Determine Risk Sources and Categories, Define Risk Parameters, Establish a Risk Management Strategy. Specific Goal is to Identify and Analyze Risks and Specific Practices are to Identify Risks, Evaluate, Categorize, and Prioritize Risks. Specific Goal is to Mitigate Risks and Specific Practices are to Develop Risk Mitigation Plans, Implement Risk Mitigation Plans.

5.3.9 Technical Solution (TS)

The policy of Technical Solution is to effectively design and develop the solutions guided by the defined standards for the process, within the scope of defined requirements and in timely fashion to meet the schedules defined in project plan.

5.3.10 Validation (VAL)

The policy of the Validation process is to ensure the effectiveness of the product and its components against the specified requirements of system, software and processes. Specific Goal is to Prepare for Validation and Specific Practices are to Select Products for Validation, Establish the Validation Environment, Establish Validation Procedures and Criteria. Specific Goal is to Validate Product or Product Components and Specific Practices are Perform Validation, Analyze Validation Results.

5.3.11 Verification (VER)

The policy of the Verification process is to ensure that the implementation of the selected work products for the project is in compliance with its specified requirements.

5.4 CMMI Level 4

Two Process areas of CMMI Level 4 are-

1. Quantitative Project Management
2. Organizational Process Performance



Fig. 5. Process areas of CMMI Level 4

5.4.1 Organizational Process Performance (OPP)

The purpose of Organizational Process Performance is to establish and maintain a quantitative understanding of the performance of the organization's set of standard processes in support of quality and process-performance objectives, and to provide the process performance data, baselines and models to quantitatively manage the organization's projects. Specific goal is to establish performance baselines and models and specific practices are to select processes, establish process performance measures, establish quality and process performance objectives, establish process performance baselines, establish process performance models.

5.4.2 Quantitative Project Management (QPM)

The purpose of the Quantitative Project Management

(QPM) process area is to quantitatively manage the project's defined process to achieve the project's established quality and process-performance objectives. Specific Goal is to Quantitatively Manage the Project and Specific Practices are to establish the Project's Objectives, Compose the Defined Processes, and Select the Sub-processes that Will Be Statistically Managed, Manage Project Performance. Specific Goal is to Statistically Manage Sub-process Performance and Specific Practices are to Select Measures and Analytic Techniques, Apply Statistical Methods to Understand Variation, Monitor Performance of the Selected Sub-processes, Record Statistical Management Data.

5.5 CMMI Level 5

Two Process areas of CMMI Level 5 are-

1. Causal Analysis and Resolution
2. Organizational Innovation and Deployment



Fig. 6. Process areas of CMMI Level 5

5.5.1 Causal Analysis and Resolution (CAR)

The purpose of Causal Analysis and Resolution (CAR) is to identify causes of defects and other problems and take action to prevent them from occurring in the future.

5.5.2 Organizational Innovation and Deployment (OID)

The purpose of Organizational Innovation and Deployment (OID) is to select and deploy incremental and innovative improvements that measurably improve the organization's processes and technologies. The improvements support the organization's quality and process-performance objectives as derived from the organization's business objectives. Specific Goal is to Select Improvements and Specific Practices are to Collect and Analyze Improvement Proposals, Identify and Analyze Innovations, Pilot Improvements, Select Improvements for Deployment. Specific Goal is to Deploy Improvements and Specific Practices are to Plan the Deployment areas, manage the Deployment, Measure Improvement Effects.

6 CMMI Appraisal Method

The CMMI Appraisal is an examination of one or more processes by a trained team of professionals using an appraisal reference model as the basis for determining strengths and weaknesses of an organization. Appraisals

require planning. When planning an appraisal of your organization, determine the scope of the organizational unit, which disciplines to include, whether the appraisal team will consist of members internal or external to your organization, projects to be included, individuals to be interviewed, and the type or class of appraisal necessary. Appraisals consider three categories of model components as defined in the CMMI. Required: specific and generic goals only. Expected: specific and generic practices only. Informative: includes sub practices and typical work products. The SEI has released two guiding documents for CMMI assessments:

6.1 Appraisal Requirements for CMMI (ARC)

Contains the requirements for three classes of appraisal methods Class A, Class B, and Class C. These requirements are the rules for defining each class of appraisal method.

6.2 Standard CMMI Appraisal Method for Process Improvement (SCAMPI)

SCAMPI is currently the only approved CMMI Class A Appraisal Method. That is, SCAMPI satisfies all the requirements of an ARC Class A Appraisal Method and has been approved by the SEI.

6.1.1 SCAMPI Class A Appraisal

A SCAMPI A appraisal is typically conducted when an organization has implemented a number of significant process improvements and needs to formally benchmark its process relative to the CMMI. A SCAMPI A is the only appraisal method that provides CMMI Maturity Level or Capability Level ratings.

6.1.2 SCAMPI Class B Appraisal

A SCAMPI B is called for when an organization needs to assess its progress towards a target CMMI Maturity Level, but at a lower cost than a SCAMPI A. SCAMPI B appraisals provide detailed findings and indicate the likelihood that the evaluated practices would be rated as satisfactorily implemented in a SCAMPI A appraisal. A SCAMPI Class B appraisal, one of three SEI appraisal methods, helps an organization understand, with a relatively high degree of confidence, the status of its software and systems engineering process relative to the CMMI. A SCAMPI B is often performed when an organization needs to accurately assess its progress towards a target CMMI Maturity Level.

6.1.3 SCAMPI Class C Appraisal

SCAMPI C appraisals are shorter and more flexible than SCAMPI A and B appraisals and are conducted to address a variety of special needs, from a quick gap analysis to determining an organization's readiness for a SCAMPI A.

SCAMPI Class C appraisals, the least formal of the SEI's suite of appraisal methods, are highly flexible and can be conducted to address a variety of needs. Typically much shorter in duration than Class A and B appraisals.

7 CONCLUSION

Each CMMI Process Area is made up of one or more goals. The goals are targets the company should establish to ensure control, visibility, and quality. These targets represent the real focus of CMMI. The CMMI structure is comprehensive; a collection of process areas, each with a defined set of goals and each goal facilitated by a set of generic and/or specific practices. An organization is considered compliant with CMMI when it demonstrates it has achieved the goals. To facilitate this effort, CMMI defines a series of practices consistent with each goal. The practices represent activities that can be deployed cohesively to meet the stated goal. As described above, each goal in CMMI usually has two or more practices associated with it. Most organizations create policies to define what their program should achieve and then establish procedures that describe the steps to be followed in carrying out each activity. To facilitate the implementation of the procedures the organization should consider creating templates, forms, and checklists that can be leveraged as new projects are sanctioned. Bottom line CMMI is absolutely vital for organizations dedicated to delivering first-class information technology products and service solutions. Because its features can be customized to meet the needs of each organization, its implementation can be light and effective with little need for complexity.

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