

# Software Process Improvement - CMMI

## What is Software Process Improvement?

Before deep diving into *Software process improvement* at first, we have to understand what is a process.

What is a process?

- It can be seen as **a method that can be used to focus the efforts of a development team towards a desired result.**
- A process integrates:
  - People (with Knowledge, Skills, Training, Motivation)
  - Tools and Equipment
  - Procedures and Methods defining the relationship of tasks
- A good process will provide clear guidance, is disciplined and constantly refined based on experience



***Software process improvement*** is the art and science of changing an organization's software process in order to build better software.

Previously, you learned to diagnose and fix problems for individual projects. When you adopt a specific tool for your project—for example, if you implement inspections on your project team and have them all follow the script.

Software process improvement is very similar, **except that instead of improving one project at a time, you work on improving the entire organization.**

While making specific improvements to the way software is built **on the scale of an individual project, there is another perspective: the high-level organizational perspective.** It's very important to diagnose chronic problems your organization is having and address them with specific practices to be adopted for all projects.

**Software process improvement always involves looking at the big picture.** This generally means writing down the entire software process as a whole and making sure that it is followed on each project. It involves not just diagnosing specific problems and attacking them individually, but also looking at entire projects and identifying areas that can be improved.

There are **specific process improvement tools** to help you do this. There are models and certifications that help you assess the state of your organization's process, and that **serve as a framework for improving that process.** There are also **processes and methodologies** you can adopt that describe the complete set of activities, roles, and work products needed to build software.

By applying these tools, you can give your organization the ability to fix problems before they get serious enough to cause your projects to slow down.

## Models and Certifications

To many experts, **software process improvement in practice means using a model or certification standard as a guideline for assessing and improving a software organization.** Some of the most common models are the **Capability Maturity Model Integration, ISO 9000, and Six Sigma.** These are not processes in and of themselves. Rather, they are systematic frameworks that were developed for evaluating any software organization (no matter what process is in use), identifying improvements that will increase the ability of the organization to build

better software, and certifying that the organization has met an objective standard for capability.

## The Capability Maturity Model Integration (CMMI)

Before deep diving Capability Maturity Model Integration (CMMI) at first, we have to understand Capability Maturity Model (CMM).

The **Capability Maturity Model (CMM)**, is a **process improvement method developed by the Software Engineering Institute(SEI) at Carnegie Mellon University in coordination with the U.S. Department of Defense (DoD)**. It provides a set of best practices meant to address important aspects of software development: productivity, performance, costs, predictability, and stakeholder satisfaction. **The purpose of the CMM is to define the characteristics of a mature, capable process in a way that can be measured and compared to processes at other organizations**

- It is a framework that is **used to analyze the approach and techniques followed by any organization to develop software products.**
- It also **provides guidelines to further enhance the maturity of the process** used to develop those software products.
- It is **based on profound feedback and development practices adopted by the most successful organizations worldwide.**

### What is Maturity?

Definitions vary but mature processes are generally thought to be –

- Well-defined,
- Repeatable,
- Measured,
- Analyzed,
- Improved, and
- Effective.

**CMM helps to solve the maturity problem by defining a set of practices and providing a general framework for improving them.** The focus of CMM is on

identifying key process areas and the exemplary practices that may comprise a disciplined software process.

### **Immature vs Mature Organization**

An immature organization would have the following characteristics

- Process improvised during project
- Approved processes being ignored
- Reactive, not proactive
- Unrealistic budget and schedule
- Quality sacrificed for schedule
- No objective measure of quality

In contrast, the characteristics of a mature organization are as follows –

- Inter-group communication and coordination
- Work accomplished according to plan
- Practices consistent with processes
- Processes updated as necessary
- Well-defined roles/responsibilities
- Management formally commits

By the late 1990s, the government and the CMM user community **had a great deal of feedback** for the SEI team responsible for maintaining the CMM. **In response, a project to create the Capability Maturity Model Integration (CMMI) was initiated in order to address these concerns.** This new version was released in 2002.

## Key Process Areas (KPA)

Both the CMM and CMMI are divided into **key process areas (KPAs)** that **define specific goals and practices**. **Each KPA addresses a specific area of software engineering**. There are several dozen KPAs, including requirements management, project planning, project monitoring, configuration management, and training.

**Each of these KPA (Key Process Areas) defines the basic requirements that should be met by a software process in order to satisfy the KPA and achieve that level of maturity.**

Conceptually, key process areas form the basis for management control of the software project and establish a context in which technical methods are applied, work products like models, documents, data, reports, etc. are produced, milestones are established, quality is ensured and change is properly managed.

The **22 process areas** are presented in alphabetical order by acronym:

- Causal Analysis and Resolution (CAR)
- Configuration Management (CM)
- Decision Analysis and Resolution (DAR)
- Integrated Project Management (IPM)
- Measurement and Analysis (MA)
- Organizational Process Definition (OPD)
- Organizational Process Focus (OPF)
- Organizational Performance Management (OPM)
- Organizational Process Performance (OPP)
- Organizational Training (OT)
- Product Integration (PI)
- Project Monitoring and Control (PMC)
- Project Planning (PP)
- Process and Product Quality Assurance (PPQA)
- Quantitative Project Management (QPM)
- Requirements Development (RD)
- Requirements Management (REQM)
- Risk Management (RSKM)
- Supplier Agreement Management (SAM)
- Technical Solution (TS)

- Validation (VAL)
- Verification (VER)

### Shortcomings of the Capability Maturity Model (CMM)

- It encourages the achievement of a higher maturity level in some cases **by displacing the true mission**, which is improving the process and overall software quality.
- **It only helps if it is put into place early** in the software development process.
- It has **no formal theoretical basis and in fact**, is based on the experience of very knowledgeable people.
- It **does not have good empirical support** and this same empirical support could also be constructed to support other models.
- **Difficulty in measuring process improvement:** The SEI/CMM model may not provide an accurate measure of process improvement, as it relies on self-assessment by the organization and may not capture all aspects of the development process.
- **Focus on documentation rather than outcomes:** The SEI/CMM model may focus too much on documentation and adherence to procedures, rather than on actual outcomes such as software quality and customer satisfaction.
- **May not be suitable for all types of organizations:** The SEI/CMM model may not be suitable for all kinds of organizations, particularly those with smaller development teams or those with less structured development processes.
- **May not keep up with rapidly evolving technologies:** The SEI/CMM model may not be able to keep up with rapidly evolving technologies and development methodologies, which could limit its usefulness in certain contexts.

- **Lack of agility:** The SEI/CMM model may not be agile enough to respond quickly to changing business needs or customer requirements, which could limit its usefulness in dynamic and rapidly changing environments.

**Capability Maturity Model Integration (CMMI)** is the successor of CMM and is a more evolved model that incorporates best components of individual disciplines of CMM like Software CMM, Systems Engineering CMM, People CMM, etc. **Since CMM is a reference model of matured practices in a specific discipline, so it becomes difficult to integrate these disciplines** as per the requirements. **This is why CMMI is used as it allows the integration of multiple disciplines as and when needed.**

The CMM Integration® project was formed to sort out the problem of using multiple CMMs. The combination of selected models into a single improvement framework was intended for use by organizations in their pursuit of enterprise-wide process improvement.

CMM describes about the software engineering alone where as CMM Integrated describes **both software and system engineering. CMMI also incorporates the Integrated Process and Product Development and the supplier sourcing.**

## CMM (Capability Maturity Model) vs CMMI (Capability Maturity Model Integration)

Aspects	Capability Model (CMM)	Maturity Model (CMMI)
Scope	Primarily focused on software engineering processes.	Expands to various disciplines like systems engineering, hardware development, etc.
Maturity Levels	Had a five-level maturity model (Level 1 to Level 5).	Initially had a staged representation; introduced continuous representation later.
Flexibility	More rigid structure with predefined practices.	Offers flexibility to tailor process areas to organizational needs.
Adoption and Popularity	Gained popularity in software development industry.	Gained wider adoption across industries due to broader applicability.

### Objectives of CMMI :

1. Fulfilling customer needs and expectations.
2. Value creation for investors/stockholders.
3. Market growth is increased.
4. Improved quality of products and services.
5. Enhanced reputation in Industry.



## **CMMI Representation – Staged and Continuous :**

A representation allows an organization to pursue different improvement objectives. An organization can go for one of the following two improvement paths. CMMI supports **two improvement paths** using levels.

### **Staged Representation – CMMI Maturity**

- The staged representation is the approach that **uses predefined sets of process areas** to define an improvement path for an organization.
- This improvement path is **described by a model component called a Maturity Level**.
- Improvement is measured using maturity levels. Maturity levels measure the maturity of a set of processes across an organization: it ranges from 1 through 5.

### **Continuous Representation – CMMI Capability**

- This approach **allows an organization to select a specific process area and make improvements** based on it.
- The **continuous representation uses Capability Levels** to characterize improvement relative to an individual process area. Improvement is measured using capability levels.
- Capability levels measure the maturity of a particular process across an organization; it ranges from 0 through 5.

Using the continuous representation enables you to achieve “capability levels.”  
Using the staged representation enables you to achieve “maturity levels.”

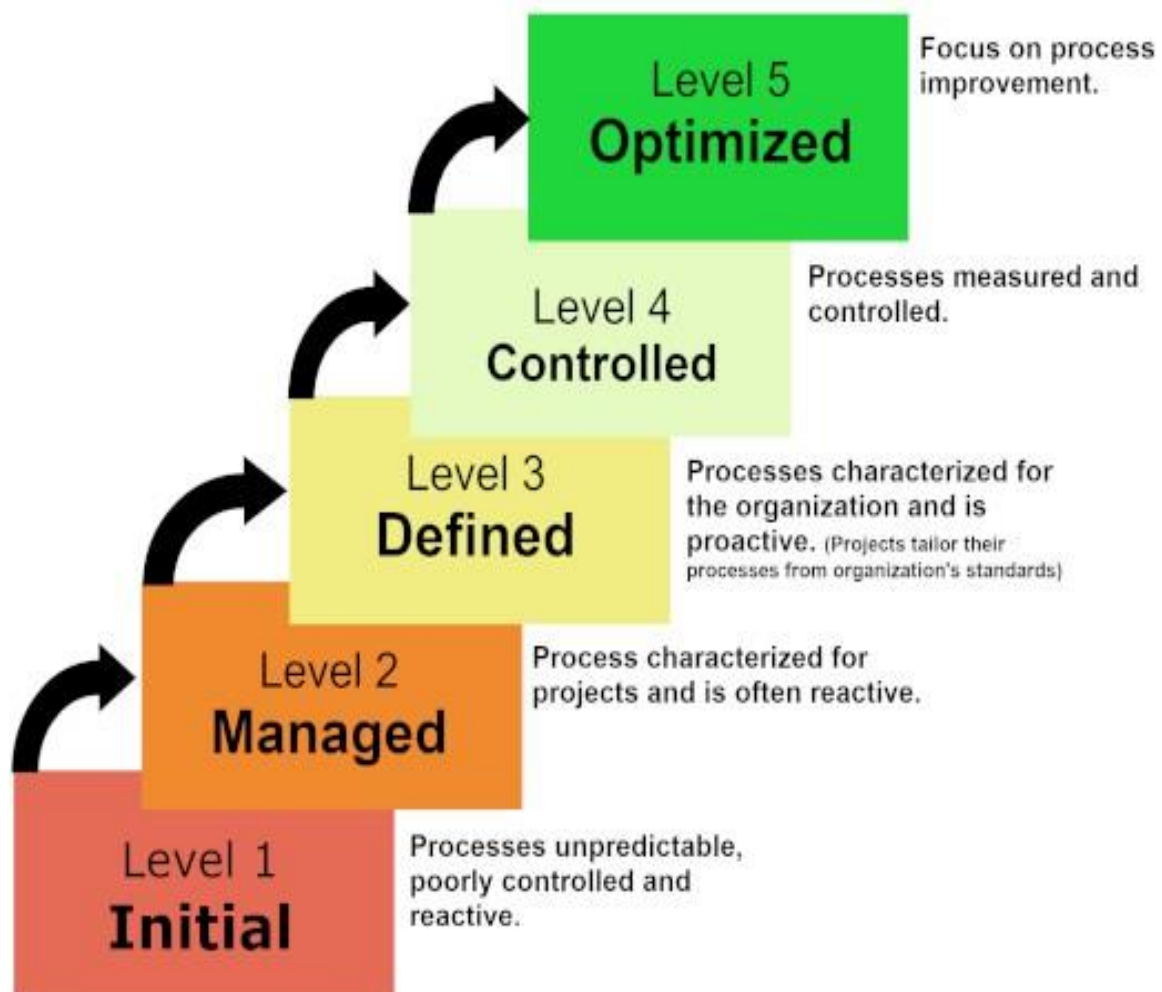
## CMMI - Maturity Levels

---

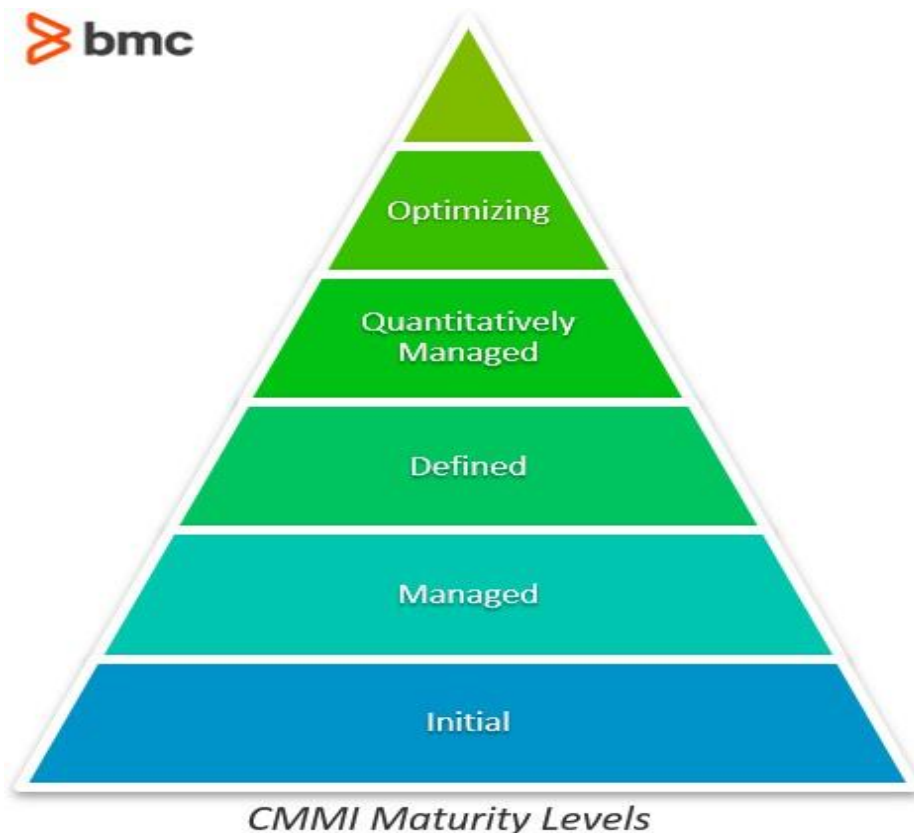
A maturity level is a well-defined evolutionary plateau (a level of attainment or achievement) toward achieving a mature software process. Each maturity level provides a layer in the foundation for continuous process improvement.

CMMI models with staged representation, have five maturity levels designated by the numbers 1 through 5.

### Characteristics of the Maturity Levels



- 1. Initial.** Processes are seen as unpredictable, poorly controlled, and reactive. Businesses in this stage have an unpredictable environment that leads to increased risks and inefficiency.
- 2. Managed.** Processes are characterized by projects and are frequently reactive.
- 3. Defined.** Processes are well-characterized and well-understood. The organization is more proactive than reactive, and there are organization-wide standards that provide guidance.
- 4. Quantitatively Managed.** Processes are measured and controlled. The organization is using quantitative data to implement predictable processes that meet organizational goals.
- 5. Optimizing.** Processes are stable and flexible. The organizational focus is on continued improvement and responding to changes.



## Maturity Level Details

Maturity levels consist of a predefined set of process areas. The maturity levels are measured by the achievement of the **specific** and **generic goals** that apply to each predefined set of process areas. The following sections describe the characteristics of each maturity level in detail.

### CMMI - Maturity Level 1 : Initial

At maturity level 1, processes are usually **ad hoc and chaotic**. The organization usually does not provide a stable environment. Success in these organizations depend on the competence and heroics of the people in the organization and not on the use of proven processes.

Maturity level 1 organizations often produce products and services that work; however, they frequently exceed the budget and schedule of their projects.

Maturity level 1 organizations are characterized by a tendency to over commit, abandon processes in the time of crisis, and not be able to repeat their past successes.

- **processes are poorly managed or controlled.**
- **unpredictable outcomes of processes involved.**
- **ad hoc and chaotic approach used.**
- **No KPAs (Key Process Areas) defined.**
- **Lowest quality and highest risk.**

### CMMI - Maturity Level 2 : Managed

At maturity level 2, an organization has achieved all the **specific** and **generic goals** of the maturity level 2 process areas. In other words, the projects of the organization have ensured that requirements are managed and that processes are planned, performed, measured, and controlled.

The process discipline reflected by maturity level 2 helps to ensure that existing practices are retained during times of stress. When these practices are in place, projects are performed and managed according to their documented plans.

At maturity level 2, requirements, processes, work products, and services are managed. The status of the work products and the delivery of services are visible to management at defined points.

Commitments are established among relevant stakeholders and are revised as needed. Work products are reviewed with stakeholders and are controlled.

The work products and services satisfy their specified requirements, standards, and objectives.

- requirements are managed.
- processes are planned and controlled.
- projects are managed and implemented according to their documented plans.
- This risk involved is lower than Initial level, but still exists.
- Quality is better than Initial level.

## CMMI - Maturity Level 3 : Defined

At maturity level 3, an organization has achieved all the **specific** and **generic goals** of the process areas assigned to maturity levels 2 and 3.

At maturity level 3, processes are well characterized and understood, and are described in standards, procedures, tools, and methods.

A critical distinction between maturity level 2 and maturity level 3 is the scope of standards, process descriptions, and procedures. At maturity level 2, the standards, process descriptions, and procedures may be quite different in each specific instance of the process (for example, on a particular project).

At maturity level 3, the standards, process descriptions, and procedures for a project are tailored from the organization's set of standard processes to suit a particular project or organizational unit. The organization's set of standard

processes includes the processes addressed at maturity level 2 and maturity level 3. As a result, the processes that are performed across the organization are consistent except for the differences allowed by the tailoring guidelines.

Another critical distinction is that at maturity level 3, processes are typically described in more detail and more rigorously than at maturity level 2. At maturity level 3, processes are managed more proactively using an understanding of the interrelationships of the process activities and detailed measures of the process, its work products, and its services.

- processes are well characterized and described using standards, proper procedures, and methods, tools, etc.
- Medium quality and medium risk involved.
- Focus is process standardization.

## CMMI - Maturity Level 4: Quantitatively Managed

At maturity level 4, an organization has achieved all the **specific goals** of the process areas assigned to maturity levels 2, 3, and 4 and the **generic goals** assigned to maturity levels 2 and 3.

At maturity level 4, sub-processes are selected that significantly contribute to the overall process performance. These selected sub-processes are controlled using statistical and other quantitative techniques.

Quantitative objectives for quality and process performance are established and used as criteria in managing the processes. Quantitative objectives are based on the needs of the customer, end users, organization, and process implementers. Quality and process performance are understood in statistical terms and are managed throughout the life of the processes.

For these processes, detailed measures of process performance are collected and statistically analyzed. Special causes of process variation are identified and, where appropriate, the sources of special causes are corrected to prevent future occurrences.

Quality and process performance measures are incorporated into the organization's measurement repository to support fact-based decision making in the future.

A critical distinction between maturity level 3 and maturity level 4 is the predictability of process performance. At maturity level 4, the performance of processes is controlled using statistical and other quantitative techniques, and is quantitatively predictable. At maturity level 3, processes are only qualitatively predictable.

- quantitative objectives for process performance and quality are set.
- quantitative objectives are based on customer requirements, organization needs, etc.
- process performance measures are analyzed quantitatively.
- higher quality of processes is achieved.
- lower risk

## CMMI - Maturity Level 5: Optimizing

At maturity level 5, an organization has achieved all the **specific goals** of the process areas assigned to maturity levels 2, 3, 4, and 5 and the **generic goals** assigned to maturity levels 2 and 3.

Processes are continually improved based on a quantitative understanding of the common causes of variation inherent in processes.

This level focuses on continually improving process performance through both incremental and innovative technological improvements.

The quantitative process-improvement objectives for the organization are established, continually revised to reflect changing business objectives, and used as criteria in managing process improvement.

The effects of deployed process improvements are measured and evaluated against the quantitative process-improvement objectives. Both the defined

processes and the organization's set of standard processes are targets of measurable improvement activities.

Optimizing processes that are agile and innovative, depends on the participation of an empowered workforce aligned with the business values and objectives of the organization. The organization's ability to rapidly respond to changes and opportunities is enhanced by finding ways to accelerate and share learning. Improvement of the processes is inherently a role that everybody has to play, resulting in a cycle of continual improvement.

A critical distinction between maturity level 4 and maturity level 5 is the type of process variation addressed. At maturity level 4, processes are concerned with addressing special causes of process variation and providing statistical predictability of the results. Though processes may produce predictable results, the results may be insufficient to achieve the established objectives. At maturity level 5, processes are concerned with addressing common causes of process variation and changing the process (that is, shifting the means of the process performance) to improve process performance (while maintaining statistical predictability) to achieve the established quantitative process-improvement objectives.

- continuous improvement in processes and their performance.
- improvement has to be both incremental and innovative.
- highest quality of processes.
- lowest risk in processes and their performance.



## CMMI - Capability Levels

---

A capability level is a well-defined evolutionary plateau describing the organization's capability relative to a process area. A capability level consists of related specific and generic practices for a process area that can improve the organization's processes associated with that process area. Each level is a layer in the foundation for continuous process improvement.

Thus, capability levels are cumulative, i.e., a higher capability level includes the attributes of the lower levels.

In CMMI models with a continuous representation, there are six capability levels designated by the numbers 0 through 5.

- 0 – Incomplete
- 1 – Performed
- 2 – Managed
- 3 – Defined
- 4 – Quantitatively Managed
- 5 – Optimizing

A short description of each capability level is as follows –

### **CMMI Capability Level 0: Incomplete**

An "incomplete process" is a process that is either not performed or partially performed. One or more of the specific goals of the process area are not satisfied and no generic goals exist for this level since there is no reason to institutionalize a partially performed process.

This is tantamount to Maturity Level 1 in the staged representation.

### **CMMI Capability Level 1: Performed**

A Capability Level 1 process is a process that is expected to perform all of the Capability Level 1 specific and generic practices. Performance may not be stable and may not meet specific objectives such as quality, cost, and schedule, but

useful work can be done. This is only a start, or baby-step, in process improvement. It means that you are doing something but you cannot prove that it is really working for you.

### **CMMI Capability Level 2: Managed**

A managed process is planned, performed, monitored, and controlled for individual projects, groups, or stand-alone processes to achieve a given purpose. Managing the process achieves both the model objectives for the process as well as other objectives, such as cost, schedule, and quality. As the title of this level indicates, you are actively managing the way things are done in your organization. You have some metrics that are consistently collected and applied to your management approach.

**Note** – metrics are collected and used at all levels of the CMMI, in both the staged and continuous representations. It is a bitter fallacy to think that an organization can wait until Capability Level 4 to use the metrics.

### **CMMI Capability Level 3: Defined**

A capability level 3 process is characterized as a "defined process." A defined process is a managed (capability level 2) process that is tailored from the organization's set of standard processes according to the organization's tailoring guidelines, and contributes work products, measures, and other process-improvement information to the organizational process assets.

### **CMMI Capability Level 4: Quantitatively Managed**

A capability level 4 process is characterized as a "quantitatively managed process." A quantitatively managed process is a defined (capability level 3) process that is controlled using statistical and other quantitative techniques. Quantitative objectives for quality and process performance are established and used as criteria in managing the process. Quality and process performance is understood in statistical terms and is managed throughout the life of the process.

## CMMI Capability Level 5: Optimizing

An optimizing process is a quantitatively managed process that is improved, based on an understanding of the common causes of process variation inherent to the process. It focuses on continually improving process performance through both incremental and innovative improvements. Both the defined processes and the organization's set of standard processes are the targets of improvement activities.

Capability Level 4 focuses on establishing baselines, models, and measurements for process performance. Capability Level 5 focuses on studying performance results across the organization or entire enterprise, finding common causes of problems in how the work is done (the process[es] used), and fixing the problems in the process. The fix would include updating the process documentation and training involved where the errors were injected.

## References

<http://www.sei.cmu.edu/cmmi/cmmi.html>

*Applied Software Project Management – Chapter 12*

SEI CMMI Tutorial ([tutorialspoint.com](http://tutorialspoint.com))

### Capability Maturity Model Integration (CMMI) - GeeksforGeeks

Once upon a time in a world of magical improvements, there was a young wizard named Harry. He found an old book of spells that was missing some pages – like trying to learn magic without all the instructions.

#### ### \*\*Level 0: Incomplete - Lost Spells\*\*

Harry found a spellbook but couldn't use it properly. It was like having only half the recipe for a potion. He couldn't do much magic, similar to when you're just starting out.

#### ### \*\*Level 1: Performed - First Magic\*\*

Undeterred, Harry started doing some spells. They didn't always work perfectly, like when you're learning to ride a broomstick and sometimes wobbling. It was a small step in learning magic, like being a beginner.

#### ### \*\*Level 2: Managed - Planning Magic\*\*

With help from experienced wizards, Harry planned his magic better. He kept an eye on things and made sure his spells were under control. It was like following a recipe and checking if everything was going well.

#### ### \*\*Level 3: Defined - Personalized Magic\*\*

As Harry got better, he found standard ways of doing magic. He mixed these with his style, a bit like making a sandwich with your favorite ingredients. His improved spells became a part of magical knowledge.

#### ### \*\*Level 4: Quantitatively Managed - Measuring Magic\*\*

Determined to get even better, Harry started measuring his spells. He used numbers and stats to see how well they worked. It was like keeping track of scores in a game – focusing on quality and performance.

#### ### \*\*Level 5: Optimizing - Improving Magic\*\*

Now a skilled wizard, Harry wanted to make his magic the best it could be. He kept making it better, like upgrading a game to have cooler features. He fixed problems and shared the improvements with others.

#### ### \*\*Conclusion: A Magical Legacy\*\*

Harry's journey through the magic levels became a famous story. His magical skills, from struggling with incomplete spells to making them perfect, inspired other wizards. And so, the magical adventure of getting better at spells continued, with everyone learning and improving together.