

Reengineering the Industrial CMMI

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Abstract: Through this research, I have established a general strategy to appraise an organization against a scale of five process maturity levels whilst maintaining a strong mechanics of CMMI. Reengineering of industrial CMMI proposes a novel method for Industrial Competence ranking of those organizations/companies which are targeting various CMMI levels. This approach uses SCAMPI assessment techniques to rank different organizations that fall below certain level of CMMI model. Furthermore, it adds the credulous factors, i.e., Score, Reliance and Confidence level for an organization's capability and maturity evaluation. The benefit of proposed model is, that an organization can set its objectives to achieve target level of CMMI model, and it could be differentiated from less mature organizations at same level. This technique not only reclassifies the CMMI levels but also exposes various confidence factors.

Keywords: CMMI, Industrial Process Optimization, Process Engineering, Capability and Maturity Ranking, Product Quality Assurance.

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I. INTRODUCTION

The Industrial capability of an organization is measured against CMMI model. The Capability Maturity Model Integration (CMMI)® is a globally-recognized set of best practices that enable organizations to improve performance, key capabilities, and critical business processes. It is used to appraise an organization against a scale of five process maturity levels. CMMI model is mainly classified into 5 distinct levels i.e. Level 1 through 5, Initial, Managed, Defined, Quantitatively Managed and Optimized respectively. Fig 1 demonstrates a framework that can be used for evaluating a process maturity. Each level ranks the organization

according to its consistency of processes in desire domain. These 5 levels show capability of an organizations or capability maturity level. It offers the integrated procedure for process improvement whilst dropping redundancy, complexity and especially the cost.

CMMI or Capability Maturity Model Integration is not only a fine grained system improvement technique that is implemented at a process level but now it befalls training and appraisal programs as well. It's a joint venture of Software Engineering Institute (a subsidiary of ISACA, Carnegie Mellon University or CMU); with industry and the government. While is being administered by SEI. CMMI models provide guidance for developing or improving processes that meet the business goals of an organization.



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In U.S. it's an essential part of Government and Department of Defense contracts, particularly in Information and Technology sphere. Software Engineering Institute (SEI, 2008) claims CMMI can be used to guide process improvement across a project, division, or an entire organization. It ensures by helping in

- Integrating conventionally separate organizational roles
- Lay down process improvement goals and priorities
- Provide support for quality processes and
- Provide a point of reference for assessing existing processes

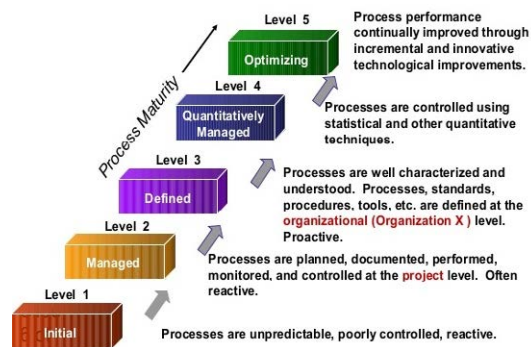


Fig 1: CMMI 5 Levels

Initially it was only concerned with software industry but with the passage of time become very popular in other domains. Though the CMM was only and directly effectual within the sphere of software but CMMI turn out to be a rebellion to encompass variety of areas. This generality of enhancement in the model makes CMMI enormously conceptual. Thus opened the door for further enhancements and reengineering of the said model. In March 2016, the CMMI Institute was acquired by ISACA. CMMI becomes very popular especially in last decade.

For a non-technical person capability is the measure of expertise. The expertise or skills are directly proportional to capability level and vice versa. At Level 1 i.e. the initial level practices are out of scope. To improve from level 1 to next level; it takes a lot of time and resources. To achieve next level there are several formal process areas need to be practiced accordingly, these areas are further divided into many endorsed activities.

Below are the key process areas under each level.

II. CMMI LEVELS

- 1.1. Initial or Maturity Level 1
 - 1.1.1. No Process Area
- 1.2. Managed or Maturity Level 2
 - 1.2.1. Configuration Management
 - 1.2.2. Measurement and Analysis
 - 1.2.3. Project Monitoring and Control
 - 1.2.4. Project Planning
 - 1.2.5. Process and Product Quality Assurance
 - 1.2.6. Requirements Management
 - 1.2.7. Supplier Agreement Management
- 1.3. Defined or Maturity Level 3
 - 1.3.1. Decision Analysis and Resolution
 - 1.3.2. Integrated Project Management
 - 1.3.3. Organizational Process Definition
 - 1.3.4. Organizational Training
 - 1.3.5. Organizational Process Focus
 - 1.3.6. Product Integration
 - 1.3.7. Requirements Development
 - 1.3.8. Risk Management
 - 1.3.9. Technical Solution
 - 1.3.10. Validation
 - 1.3.11. Verification
- 1.4. Quantitatively Managed or Maturity Level 4
 - 1.4.1. Organizational Process Performance
 - 1.4.2. Quantitative Project Management
- 1.5. Optimizing or Maturity Level 5
 - 1.5.1. Causal Analysis and Resolution
 - 1.5.2. Organizational Performance Management

The above levels are strictly defined and are distinct process areas of CMMI levels. For stirring to subsequent level from the prior level an organization has to work through several different process areas. An organization that has worked on many process areas (but not on all), still considered on previous level, though practically it is more capable than the one that doesn't worked even on single process area. A general worldwide Percentage of Organizations against each level is shown in Fig 2. Starting

from initial level, 16.9 percent of organizations working at level 1, while 43.2 on level 2 and so on. But dozens of organizations are in transition period i.e. near to enter the next level. Whether an organization is achieving all objectives to catch the next level or just making the first move; we can't analyze the maturity difference.

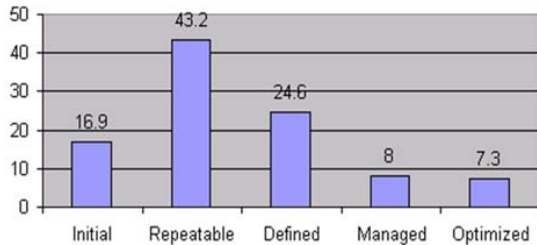


Fig 2: Distribution of Organizations according to CMMI Levels (Worldwide)

Organizations with enormous capability difference are still considered at the same level, thus badly affect the conclusions. In this paper the capability and maturity evaluation issue is being resolved by reengineering the industrial CMMI (Capability Maturity Model Integration). For evaluating single process area, SCAMPI (Standard CMMI Appraisal Method for Process Improvement) is an appropriate approach, in this case.

III. PROPOSED MODEL

Normally client is never concerned about the developmental details of the product rather fretful about the skills and expertise of the developing organization. For gigantic size projects customer needs higher CMMI levels, whereas for smaller projects lower levels are also acceptable. Idea behind this research paper is to categorize the difference of maturity and capabilities of organizations working at same level of CMMI. This paper answers the following question.

How to rank different organizations that fall under the same level of CMMI model?

Furthermore, it adds the credulous factors, i.e., Score, Reliance and Confidence level for an organization's capability and maturity.

IV. THE SCAMPI

Here we are using an SEI's well-known technique named SCAMPI (Standard CMMI Appraisal Method for Process Improvement). It presents benchmarks for quality scoring to CMMI models. These techniques are not only useful to mark the effectiveness of the current processes but also unveil their limitations. SCAMPI identify the assessment process as consisting of grounding;

- On-site behavior;
- Foundation clarification, conclusion, and ratings;
- Final reporting; and
- Ensuing activities.

The set of credentials related with a meticulous edition of the CMMI incorporates a requirements design called the Appraisal Requirements for CMMI (ARC). ARC lays down 3 levels of rule for appraisals i.e. Class 'A', 'B', and 'C'. The Class 'A' SCAMPIs are accomplished by SEI's official Lead Appraisers who employ the SCAMPI A Method Definition Document (MDD), this rating ranges from Level 1 (lowest) to Level 5 (highest)).

V. SCAMPI ASSESSMENTS

To evaluate CMMI level of an organization CMMI Institute introduced three assessment classes. The class 'A' is more formal and thus results in a complete Capability Maturity Level Rating of an organization, called "SCAMPI A Assessment". While class B and class C are not very formal and results in just overview of practices being followed.

VI. SCORE

After the 'SCAMPI "A" Assessment' for CMMI Level, score for each process area is calculated. The score is the number of goals achieved against the total number of goals (both specific goals and generic goals). In table 1.1 to table 1.5 various process areas in corresponding levels are assigned scores. The Process Area Score or simply score is represented in percentage. In each case minimum possible value is 0 and maximum possible value is 100 for a single process area.

Table 1.1: CMMI Level 1 Process Area Score

Process Area	Abbreviations	Score
Level 1 INITIAL		
No Process Area	NA	

Table 1.2: CMMI Level 2 Process Area Score

Level 2 MANAGED		
Requirements Management	REQM / m ₁	0-100
Project Planning	PP / m ₂	0-100
Process and Product Quality Assurance	PPQA / m ₃	0-100
Configuration Management	CM / m ₄	0-100
Project Monitoring and Control	PMC / m ₅	0-100
Measurement and Analysis	MA / m ₆	0-100
Supplier Agreement Management	SAM / m ₇	0-100

Table 1.4: CMMI Level 4 Process Area Score

Level 4 QUANTITATIVELY MANAGED		
Organizational Process Performance	OPP / q ₁	0-100
Quantitative Project Management	QPM / q ₂	0-100

Table 1.3: CMMI Level 3 Process Area Score

Level 3 DEFINED		
Decision Analysis and Resolution	DAR / d ₁	0-100
Integrated Project Management	IPM / d ₂	0-100
Organizational Process Definition	OPD / d ₃	0-100
Organizational Training	OT / d ₄	0-100
Organizational Process Focus	OPF / d ₅	0-100
Product Integration	PI / d ₆	0-100
Requirements Development	RD / d ₇	0-100
Risk Management	RSKM / d ₈	0-100
Technical Solution	TS / d ₉	0-100
Validation	VAL / d ₁₀	0-100
Verification	VER / d ₁₁	0-100

Table 1.5: CMMI Level 5 Process Area Score

Level 5 OPTIMIZING		
Causal Analysis and Resolution	CAR / o ₁	0-100
Organizational Performance Management	OPM / o ₂	0-100

VII. COMPETENCE

Competence Rank is the internal capability of an individual CMMI Level. If an organization is already assessed using SCAMPI 'A' assessment, then it could be re-assessed using SCAMPI B assessment for Competence ranking. To find the Competence ranking for an individual CMMI level we need to know the scoring of each process area. Then we calculate the geometric mean of all the scores, which is 'Competence Rank' for CMMI Level. If 'P' is the process area then Eq 1 shows a generic formula for Competence Rank of CMMI's certain level.

Competence Ranking or $\mathcal{C} = (P_1 \times P_2 \times P_3 \times \dots \times P_n)^{1/n}$
or

$$\mathcal{C} = \sqrt[n]{\prod P_n}$$

Eq1

Competence rank shows the capability of an organization working below certain CMMI level. The introduction of Competence Ranking technique has opened a door to distinguish the higher capability against the lower one, being working under same level of CMMI. In the below equations i.e Eq 1.1 to Eq 1.4, a competence ranking of corresponding level is being calculated.

✓ Targeting level 2 (managed)

$$\mathcal{C}_2 = (m_1 \times m_2 \times m_3 \times m_4 \times m_5 \times m_6 \times m_7)^{1/7}$$

Eq 1.1

✓ Targeting level 3 (defined)

$$\mathcal{C}_3 = (d_1 \times d_2 \times d_3 \times d_4 \times d_5 \times d_6 \times d_7 \times d_8 \times d_9 \times d_{10} \times d_{11})^{1/11}$$

Eq 1.2

✓ Targeting level 4 (quantitatively managed)

$$\mathcal{C}_4 = (q_1 \times q_2)^{1/2}$$

Eq 1.3

✓ Targeting level 5 (optimized)

$$\mathcal{C}_5 = (o_1 \times o_2)^{1/2}$$

Eq 1.4

VIII. CONFIDENCE LEVEL

In the next step we are going to find the confidence level of an organization. Minimum score of the process area among all processes areas is called the confidence level. It assures that all process areas are working higher than said point and thus increases the confidence of customer. To find the confidence (\mathcal{C}) at each

CMMI Level, the following equations are used i.e Eq 2.1 to Eq 2.4.

✓ Targeting level 2 (managed)

$$\mathcal{C}_2 = \text{Min}(m_1, m_2, m_3, m_4, m_5, m_6, m_7)$$

Eq 2.1

✓ Targeting level 3 (defined)

$$\mathcal{C}_3 = \text{Min}(d_1, d_2, d_3, d_4, d_5, d_6, d_7, d_8, d_9, d_{10}, d_{11})$$

Eq 2.2

✓ Targeting level 4 (quantitatively managed)

$$\mathcal{C}_4 = \text{Min}(q_1, q_2)$$

Eq 2.3

✓ Targeting level 5 (optimized)

$$\mathcal{C}_4 = \text{Min}(o_1, o_2)$$

Eq 2.4

IX. RELIANCE

Reliance is another feature which in fact embodies the constancy in all process areas for the particular level. Here we need standard deviation to calculate reliance of a certain level of CMMI. 1st we calculate the Standard Deviation (SD or σ “sigma”) from the scores of all process areas. This SD is then subtracted from the maximum standard deviation and call as reliance of an individual CMMI Level. As shown below in Eq 3.1.

$$R = 50 - \delta$$

Eq 3.1

This reliance ranges from 0 to 50. The maximum value of reliance (i.e when $R = 50$)

shows a harmonized improvement in all process areas. It shows that an organization has gained the equal maturity (capability and maturity) in all process areas. While on the other hand lower reliance represents uneven improvement in various process areas. Impact of this feature varies from project to project. In some projects higher maturity (capability and maturity) of few process areas is good enough while in other cases same maturity (capability and maturity) is worthier. In table 2 a general reliance is classified into 5 classes. This classification is not the final version but can be modified in different circumstances.

Table 2: General Reliance Classification

S#	R	Rank
1	40<	Highest reliance
2	30-40	Higher reliance
3	20-30	Moderate reliance
4	10-20	Lower reliance
5	>10	Lowest reliance

X. PROPOSED CLASSIFICATION

To better visualize the concept of above discussion, a general classification of organization’s capability and maturity is sketched below. This is not the final classification but a proposed model to understand the purpose of research. Using this technique we can design many other models depending upon our needs.

Tables 3.1 to 3.4 summarize the proposed models.

- Table 3.1 classifies Competence Rank of CMMI Level 4 targeting Level 5.
- Table 3.2 classifies Competence Rank of CMMI Level 3 targeting Level 4.
- Table 3.3 classifies Competence Rank of CMMI Level 2 targeting Level 3.
- Table 3.4 classifies Competence Rank of CMMI Level 1 targeting Level 2

Table 3.1: Classification of Competence Rank of CMMI Level 4

S#	COMPETENCE RANK (C) INTERVAL	CONFIDENCE LEVEL (L) EQUAL OR GREATER	CLASS
0	100	100	CMMI 5
1	80-100	70	L4A
2	60-80	50	L4B
3	40-60	30	L4C
4	20-40	10	L4D
5	10-20	5	L4E

Table 3 2: Classification of Competence Rank of CMMI Level

S#	COMPETENCE RANK (C) INTERVAL	CONFIDENCE LEVEL (L) EQUAL OR GREATER	CLASS
0	100	100	CMMI 4
1	80-100	70	L3A
2	60-80	50	L3B
3	40-60	30	L3C
4	20-40	10	L3D
5	10-20	5	L3E

Table 3.3: Classification of Competence Rank of CMMI Level 2

S#	COMPETENCE RANK (G) INTERVAL	CONFIDENCE LEVEL (L) EQUAL OR GREATER	CLASS
0	100	100	CMMI 3
1	80-100	70	L2A
2	60-80	50	L2B
3	40-60	30	L2C
4	20-40	10	L2D
5	10-20	5	L2E

to redesign the number of different classification models for different purposes. Like the one we drew above in which capabilities are classified into five classes' i.e. A – E depending upon performed practices of CMMI Levels. For a common person we can call Expertise or skills classification model of different organizations or Expertise Level of an organization.

Table 3.4: Classification of Competence Rank of CMMI Level 1

S#	COMPETENCE RANK (G) INTERVAL	CONFIDENCE LEVEL (L) EQUAL OR GREATER	CLASS
0	100	100	CMMI 2
1	80-100	70	L1A
2	60-80	50	L1B
3	40-60	30	L1C
4	20-40	10	L1D
5	10-20	5	L1E

XI. CONCLUSION

Despite the vast research in evaluating the capability and maturity of various organizations, still there exist vast uncategorized holes. The overall image that emerges from the literature is not enough to conquer this dilemma. This reengineering reveals the innovative assessment through CMMI manifesto. This paper introduces the interesting capability factors i.e. Score, Competence Rank, Confidence Level and the Reliance. These factors are used to make a distinction between higher and lower capabilities of organizations, practicing below certain CMMI Level. Thus provides more details about an organization than CMMI model. This way customer is more flexible and contented for selecting development organization, without being endured the depth of mechanics. A new and more incredible aspect of this approach is

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