Leveraging CMMI framework for Engineering Services

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Introduction

In response to Global market demand, several OEMs adopt Global Engineering as their business strategy in order to reach out to fast growing emerging markets and also to bring out faster and cheaper products [1].

Most OEMs outsource their global engineering activities to Global Partners to achieve operational efficiency, flexibility and agility by utilizing the engineering talent of global workforce.

Global Engineering has now progressed from traditional Engineering Services like Computer Aided Design (CAD), Computer Aided Engineering (CAE), Computer Aided Manufacturing (CAM) and Product Data Management (PDM) to product development activities spanning across the product lifecycle starting with capturing Voice of Customer, Product Specifications, Conceptual Design, Product Risk Analysis, Detailed Design, Product Validation, Manufacturing Process Design, Manufacturing Sourcing, Prototype development and production support (Figure 1).

Figure 1 Evolution of Engineering Services

Since Global Engineering partners carry out product development activities for OEMs, their processes should align to the Product development Processes of OEMs in order to fulfill the OEMs’ priorities for speed-to-market and competitive products with consistent quality.

Product Development Process

A typical Product Development Process (Figure 2) has following phases [2]:

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i. **Idea Generation**: Ideas for new product are obtained based on the analysis of market and consumer trends

ii. **Opportunity Assessment**: Ideas are screened based on market potential, commercial feasibility, technical viability, impact on current products, resources availability, health & environmental impact and other factors related to safety, reliability, regulatory, statutory etc

iii. **Concept Development & Testing**: Technical requirements of the product are derived based on opportunity assessment and Voice of Customer. Alternate design concepts in the form of mock up models are developed and feedback is obtained from a focus group of users to determine customer willingness to buy the product

iv. **Business Analysis**: Selling price, sales volume, profitability and breakeven point for the product are estimated and fitness of new product within the company’s strategy is confirmed

v. **Prototype Development & Testing**: The functional, peripheral and control elements required to make selected concept work as a product are identified; functional requirements and performance characteristics of each of these elements are established. System design is further drilled down into detailed design & drawings of components and assembly with manufacturing and assembly details. Prototypes are developed and are tested in simulated & user environment to ensure that the product works as intended. Customer inputs on prototype is taken from a test market

vi. **Product manufacture**: Manufacturing drawings are prepared, production planning is carried out, sourcing requirements are determined before full scale production of the product starts

vii. **Product Launch**: Product catalogs, user manuals, installation & maintenance manuals, marketing material are prepared. Pre-market notification to regulatory authorities that may be needed is done and then product is launched. Feedback on product from end users post launch is collected, analyzed and corrective actions are implemented in current product or subsequent product versions

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**Figure 2 Product Development Process**
There are toll gates at the end of every phase; these are decision making milestones to verify

- how well the product requirements are being met in every phase of development process
- whether the product being developed is in alignment to company’s strategy
- whether the development can progress to the next phase

The tollgates also help in setting priorities for assigning resources to product development activities

**Challenges in Product development process**

There are several challenges the OEMs face during product development (Figure 3):

- Focus on quality right from early stages of development as errors detected later will be difficult and costly to fix
- Agility to changing requirements of end customer during a new product development while at the same time meeting product launch schedules
- Ensuring seamless collaboration of multi-disciplinary teams / globally distributed teams during product development
- Focus on innovation so as to develop Innovative Products with newer technologies, more features and increased value

**Figure 3 Challenges in Product Development**

- Reduced development time & Cost
- Productivity Improvement
- Quality Focus
- New Technologies
- Changing Requirements
- Global Partners / Suppliers
- Multi Disciplinary teams
- Diverse Market Needs

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- Continuous improvement of development processes to demonstrate better productivity, reduced product development time and cost
- Regulatory and homologation requirements of different markets and incorporating these into the design and development processes
- Ensuring that the suppliers & partners understand the objectives of product development

The OEMs need to take a systemic approach to manage these challenges that spread across different phases of product development so that their business objectives are met.

In addition OEMs also need to estimate their ability to meet cost, quality and schedule goals during product development so that they remain competitive.

In this paper, the authors will discuss how CMMI® Model can be leveraged by OEMs to manage and improve their product lifecycle processes from concept to delivery and maintenance.

**Capability Maturity Model**

CMMI® (Capability Maturity Model® Integration) for Development formulated by Software Engineering Institute (SEI) is a process improvement maturity model for development of products [3]. Even though it has been widely adopted by IT companies for software development, this model with its comprehensive integrated approach covering processes from concept to delivery and maintenance of a product can be used by OEMs belonging to any industry.

As per a 2010 SEI report [4], out of 4222 organizations that have reported their CMMI appraisal results, 24.2% are into Engineering & Management services and 15.7% are into manufacturing of industrial machinery & equipments, electronics & electrical equipments, transportation equipments, instruments and other products.

CMMI has been developed based on best practices in product development and maintenance activities of different organizations. It focuses on improving the processes addressing the key dimensions of an organization namely – People, Procedures, Tools & technology (Figure 4).

![Figure 4 Key Dimensions in an Organization](image-url)
The CMMI Model lays emphasis on processes to leverage

- People and their knowledge to do product development activities better & increase scalability
- Tools to improve productivity and reduce time to market
- New Technology to improve competitiveness of products
- Procedures to integrate globally distributed development teams to ensure consistent product quality

The model can also be used as a guide to develop processes, appraise current processes and improve the processes related to any discipline of product development viz. mechanical, electrical, electronic and software as well as other organizational processes that are essential for effective and efficient product development.

Subsequent sections will cover the key aspects of CMMI framework which will help the OEMs to improve their product development activities.

**Key Aspects of CMMI Framework**

CMMI Framework provides an evolutionary path comprising of maturity levels to improve processes in an organization. There are 5 maturity levels (Figure 5):

1. *Initial*: In this level, processes are ad hoc and informal
2. *Managed*: In this level, there are disciplined processes for managing projects
3. *Defined*: In this level, there are standard processes to ensure consistency across organization
4. *Quantitatively Managed*: In this level, the organization can predict the performance of processes with respect to their objectives
5. *Optimizing*: In this level, processes are continually improved

Each maturity level comprises of specific and generic practices for a defined set of process areas and maturity levels are measured through achievement of specific and generic goals attached to each process area.

Above is a staged representation of the model providing the organizations a structured way for process improvement so they can focus their efforts on manageable number of process areas at a time.

An organization may also choose to improve performance of a single process that has issues; continuous representation of CMMI model with capability levels can be used in this case.
In CMMI, processes in an organization are grouped into 4 categories:

- Engineering processes
- Project management processes
- Process management processes
- Support processes

While the Engineering Processes of CMMI cover the activities of Product Development Process explained earlier, Project Management, Process Management and Support processes cover activities needed for successful completion of a project and for institutionalizing the processes across the organization.

In subsequent sections we will see the best practices provided by CMMI framework in each of the above process categories which organizations involved in product development can adopt.

**Engineering Processes:**

CMMI provides engineering processes that are needed to transform customer needs and requirements into a complete product; these cover entire product lifecycle and can be used by any engineering discipline / department – mechanical, electrical, software etc – involved in product development in an organization (Figure 6).

The Engineering Processes are:

- Requirements Development
- Requirements Management
- Technical Solution
- Product Integration
- Verification
- Validation
Some of the key practices given by CMMI in the above processes are:

(i) Requirements Development:
- Eliciting needs of stakeholders - customers, end users, designers, testers, suppliers, manufacturers, service personnel
- Translating the needs into product, component and interface requirements
- Developing concepts / scenarios to define product environment, its functionalities, boundaries and constraints
- Prototyping / simulation to validate the requirements

(ii) Requirements management:
- Establishing an understanding of the requirements to the product development teams
- Getting commitment to requirements from customer as well as project teams
- Managing any changes to requirements based on evaluation of impact to cost, effort, schedule and product performance
- Maintaining bi-directional traceability between requirements and work products
- Ensuring consistency between requirements and project plan / activities

(iii) Technical Solution:
- Evaluating & selecting design concepts to satisfy the product requirements
- Developing detailed design from selected design concept with manufacturing details of the components & product
- Developing the design as components

(iv) Product Integration
- Assembling of components into a product taking care of the assembly and external interface requirements and functionalities of the product
- Packaging & delivery of the product / component to the customer
(v) Verification:
- Reviewing of components / product against specified requirements at different stages of the product development lifecycle

(vi) Validation:
- Ensuring that the component / product fulfills its intended use in the intended environment
- Involving end users and other stakeholders in the validation

The Engineering Processes provide a systems engineering approach to product development and emphasize on concurrent development. Also the CMMI framework ensures that these engineering processes (e.g. Requirements development, verification) are applied repeatedly during product development so that quality in all components of the product is ensured before delivery to customer.

Project Management Processes:

These are project level processes for planning, monitoring, and controlling the project, managing project risks, managing project stakeholders and suppliers and applying statistical techniques to manage process and product quality (Figure 7).

Project Management Processes are:

- Project Planning
- Project Monitoring and Control
- Supplier Agreement Management
- Integrated Project Management
- Risk Management
- Quantitative Project Management

![Figure 7 Project Management Processes](image-url)
Some of the key practices given by CMMI in Project Management are:

(i) **Project Planning:**
- Developing a Work Breakdown Structure for organizing the project scope into manageable work units
- Developing Estimation Models & estimating project effort, schedule and cost
- Define Project Life cycle phases and decision making tollgates
- Developing Detailed project plan with budget & schedule considering constraints, dependencies and risks
- Developing Data management plan for access and security of product design & development data across integrated product development teams
- Establishing Resources Plan, Competency development Plan, Stakeholder Involvement Plan
- Obtaining commitment from the stakeholders

(ii) **Project Monitoring & Control:**
- Monitoring of project elements – schedule, cost, effort, resources, skill levels, risks, stakeholder involvement
- Conducting project & milestone reviews
- Taking corrective actions when there is deviation in project plan

(iii) **Supplier Agreement Management:**
- Identifying components / products that are to be acquired from suppliers
- Selecting suppliers based on established criteria
- Establishing supplier agreements
- Evaluating supplier performance as defined in agreements
- Evaluating products from suppliers

(iv) **Integrated Project Management:**
- Establishing project process by tailoring organization’s standard process
- Ensuring that all stakeholders of integrated project team understand the shared vision of the project
- Ensuring that the stakeholders perform their activities for successful completion of project
- Storing of project documents and experiences in organization’s process assets library

(v) **Risk Management:**
- Identifying risks in design, manufacturing, assembly and service of the product
- Determining the impact, probability of occurrence of risks
- Use of risk database to identify sources of risk
- Prioritizing the risks for mitigation
- Establishing risk management strategy

(vi) **Quantitative Project Management:**
- Applying statistical techniques to manage the process & quality objectives of the project
- Taking corrective actions whenever there are process variations due to special causes
Project Management Processes of CMMI framework provide a systematic approach to the organizations involved in product development by ensuring timely involvement of relevant stakeholders in the product lifecycle and ensure effective management of all elements of product development for accomplishing the objectives of the project.

**Process Management Processes:**

These are organizational level processes to plan & deploy process improvements, to define standard processes & assets, to identify training needs and develop training programs, to develop a quantitative understanding of performance of processes, to deploy incremental and innovative improvements across an organization (Figure 8).

Process Management Processes are:

- Organizational Process Focus
- Organizational Process Definition
- Organizational Training
- Organizational Process Performance
- Organizational Innovation & Deployment

![Figure 8 Process Management Processes](image)

Some of the key practices in Process Management are

(i) **Organizational Process Focus:**

- Creating a process group to
  - Define objectives of processes
  - Identify improvements to organizational processes based on:
    - process measurements

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- experiences from earlier projects
- product feedback
- benchmarking with other organizations
- findings from appraisals / audits

- Deploy improvements
- Monitor deployment to ensure that the defined quality and process performance objectives are met

(ii) Organizational Process Definition:

- Developing a process assets library comprising of standard processes for product lifecycles
- Developing Tailoring guidelines to help the projects to derive their processes from the organization’s standard processes
- Sharing of best practices and lessons learnt across project teams

(iii) Organizational Training:

- Establishing a training program with instructional resources to support strategic objectives
- Providing training to integrated project teams
- Assessing the effectiveness of training to ensure that the organization’s objectives are met

(iv) Organizational Process Performance:

- Providing a quantitative understanding of the performance of the product development processes
- Defining targets and tolerances for various metrics based on organization’s objectives
- Establishing process performance baselines for these measures
- Analyzing process performance against capability baselines & targets
- Implementing improvement actions to eliminate process instability
- Developing forecasting models to predict performance of the product development processes

(v) Organizational Innovation & Deployment:

- Deploying incremental and innovative improvements based on quantitative feedback from the product development processes
- Piloting of improvements to evaluate the benefits against the cost and impact to the organization before deployment
- Measuring results from these improvements to ensure their effectiveness in meeting objectives of the organization

The above organizational processes ensure institutionalization of consistent processes across product development teams and help in achieving objectives related to product quality, time to market, product development time, end user satisfaction, productivity etc

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Support Processes:

Following CMMI processes support product development and maintenance activities (Figure 9):

- Configuration Management
- Process & Product Quality Assurance
- Measurement & Analysis
- Decision Analysis & Resolution
- Causal Analysis & Resolution

Some of the key practices in Support Processes are

(i) Configuration Management:

- Ensuring integrity of work products like product specification, design data, drawings, code during product development
- Establishing baselines of work items like requirements specifications, design documents, code, models, drawings etc.

(ii) Process & Product Quality Assurance:

- Establishing Quality Assurance practices to objectively evaluate processes, products and services
- Providing feedback to management on the results of quality assurance activities

(iii) Measurement & Analysis:

- Establishing measurement objectives
- Defining measures, procedures for data collection, storage, analysis and communication of results
- Sustaining measurement capability to support information needs of the management
(iv) Decision Analysis & Resolution:
- Establishing processes to decide which issues should be subjected to formal evaluation methods
- Applying these methods at different stages of product development e.g. to evaluate alternate design concepts, to evaluate risks related to design / process / system or to make or buy decision for components

(v) Causal Analysis & Resolution:
- Establishing Processes to identify the causes to defects and other problems and take corrective actions to prevent recurrence in future.

These support processes help in establishing controls and help in making informed decisions during product development.

Conclusion

As seen in this white paper, CMMI processes can be adopted by organizations involved in product development

- As a guide to carry out process improvements in a project or across product development teams or across the organization
- To identify essential elements in each process area of product development and to set process improvement goals & priorities and as reference for appraising current processes
- To provide an organizational vision for process improvement covering all processes in the organization and all engineering disciplines of product development
- To help achieve the strategic objectives through competitive products, reduced time to market, high quality products and increased end user satisfaction

By adopting CMMI, global engineering partners of OEMs, can differentiate their products and services and can provide objective evidence of benchmarking of their processes to the best in class in the industry.

Also, through CMMI process framework, global engineering partners can improve their market competitiveness through improved productivity and reduced development cost.

Several organizations have reported quantitative process improvements attributable to CMMI adoption [5].

Engineering & Industrial Services (EIS), an operating unit of Tata Consultancy Services has incorporated CMMI into the global engineering processes; in 2000 TCS had the first Engineering Delivery Centre certified for CMM level 5 and has since been getting re-certified for CMMI level 5 for all global delivery operations of EIS. CMMI framework has helped in institutionalizing global engineering processes of TCS across all its project teams in alignment to strategic priorities of OEMs.

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References:

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