

Overview of Capability Maturity Model (CMM)

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1. Introduction

1.1 Background

The Capability Maturity Model (see RD1) came about as a result of the Software Engineering Institute (<http://www.sei.cmu.edu/sei-home.html>) being asked by the US DOD to come up with an approach of evaluating software subcontractors. The resulting approach or model relies on the assumption that

Organisation's mastery of IT *Depends on* **Level of mastery of development processes** + **Level of technology reached & its coherence with processes used**
(5 levels in CMM) *(2 levels in CMM)*

In theory one can then classify an organisation within a grid of 10 positions. In practice, some of the positions won't arise as illustrated by the following from RD2:

B Basic		Methods standards	Standard SW process	Data collected & Quantified	Zero Errors (!)
A Ineffectual	Serious cost & schedule problems	Methods standards	Standard SW process	Data collected & Quantified	
	1 Initial	2 Repeatable	3 Defined	4 Managed	5 Optimizing

Legend:

Black means that "B & 1" and "A & 5" are very unlikely to be true at same time.

Grey means that it is quite possible "B & 2" to occur together; similarly, for "A & 4".

1.2 Outline of levels

1.2.1 Process mastery

1. Initial: Procedures and lines of authority are badly defined.

Organisation does not apply sound software engineering principles in a coherent way to software development

Organisation does not use technology and modern tools, or else uses them badly.

2. Repeatable: Generally, the organisation has learned how to manage cost and schedule.

Repeatable processes are in place.

Standard methods are used to manage such activities as cost estimation, planning, change management of specifications and code, and project reviews.

3. Defined: Processes are well defined and reasonably complete.

The procedures are defined in terms of SW engineering standards & methods.

Improvements have been effected in both methods and organisational structure. In particular, improvements have been made in design & code reviews, and training programs have been established for programmers and review moderators.

A key improvement is putting in place of a dedicated SW engineering group.

4. Managed: Processes are not only understood but are also quantified, measured and quite well mastered.

The organisation bases its operational decisions on quantified data. Analysis is focussed on data collected during reviews and tests.

Tools are used to improve process mastery and management, as well as to collect and analyse data.

Estimates of error rates are reasonably accurate.

5. Optimized: Organisation has not only achieved a high degree of mastery of the different processes but is also oriented towards improvement and optimization of these processes. This implies that there is sophisticated analysis of collected data on errors and costs, and that investigations are made of the causes of errors and how to prevent them. The data are analysed iteratively to improve processes and to achieve optimal performance.

1.2.2 Technological mastery

A. Ineffectual: While there may be several tools and automated methods in use within the organisation, the technology is either not very good or is not being used effectively.

B. Basic: Technologies of proven effectiveness are in place. An organisation that uses proven basic software development technology will be reasonably effective and, depending on its mastery of processes, will regularly deliver satisfactory performance.

1.3 Some general remarks on CMM

(a) We present here an outline of the basic CMM but be aware that there have been substantial developments over the years. In particular, CMM was upgraded to CMMI (Capability Maturity Model Integration) in 2000.

(b) According to RD2 (which is quite a while ago!), about 80% of organisations were at level 1 or 2 of process mastery, and at level A of technological mastery. It would be interesting to see some recent data on this! For example, see <http://members.nasscom.org/QualityCertified.asp> (checked April 1, 2005) for list of organizations who have achieved various CMM levels. According to http://www.nasscom.org/artdisplay.asp?Art_id=2087 “Fewer than 100 companies in the world have been assessed at a CMM Level 5 rating.”

(c) If CMM is introduced into an organisation in an inappropriate way, there is a real risk of documentation overload with no real long term benefits.

(d) A more detailed outline of levels 2 to 5 is given below.

1.4 Reference documents

RD1 Paulk et al, The Capability Maturity Model: Guidelines for improvement of the software process, Addison-Wesley 1995

RD2 Martin, Qualité du logiciel et système qualité, Masson 1992

1.5 Glossary, Acronyms & Abbreviations

Ag't	Agreement
app.	approved
B/L	Baseline (Here, shorthand for system req'ts forming basis for SW)
chg	Change(s)
cmts	Commitments
comms	communications
comp	computer
Configure	Includes "Identify, control, make available"
dev/imp	SW process development and improvement
ext	external
KPA	Key Process Area
proc.	procedure (or, sometimes, process)
Proj Mgt	Project Management (may be wider than just SW Proj Mgt)
QM	Quality management
SCM	Software Configuration Management
Sen Mgt	Senior Management
SPI	Software Process Improvement
SQA	Software Quality Assurance
SQM	Software Quality Management
SW eng	Depending on context may mean SW engineering personnel

2. CMM Level 2 - Repeatable

KPA ->	Requirements Management	SW Project Planning	SW Proj. Tracking & Oversight	SW Subcontract Management	SW Quality Assurance	SW Configuration Management
Goals	1.Control Sys Req B/L 2. Keep SW processes consistent with B/L	1.Document SW estimates 2.Plan & document project activities & commitments 3.Affected people agree	1.Track actual vs. plans 2.Correct for deviations between actual & planned 3.Affected people agree chg	1.Pick qualified SW contr'rs 2.Parties agree cmts 3.Parties maintain comms 4.Track perfor'nce vs cmts	1.Plan SW QA activities 2.Objec've check vs stds etc 3.Inform those affected 4.'Promote' unresolvables	1.Plan SCM 2.'Configure' selected items 3.Control changes 4.Do status accounting
Commitment to perform	1.Written policy for Sys Req management	1.Designate SW Proj Mgr 2.Follow written policy for SW project planning	1.Designate SW Proj Mgr 2.Follow written policy for SW project management	1. Written policy for SW subcontract management 2. Designate subcont. Mgr	1. Written policy for SW QA implementation	1. Written policy for SW CM implementation
Ability to perform	1.Establish responsibility for Sys Req analysis 2.Doc Sys Req alloc. to SW 3.Resource B/L manage'nt 4.Training for B/L mgt.	1.Documented & approved SOW exists 2.Respon. for SDP assigned 3.Adequate SDP resources 4.Adequate plan'ng training	1.Doc. & app. SDP exists 2.PM assigns responsib'ities 3.Adequate resources 4.Adequate PM training 5.Adequate tech orientation for first line managers	1. Adequate resources 2. Adequate training 3. Adequate tech orientation for SW managers & similar	1.SQA group exists 2. Adequate resources 3. Adequate training 4.SW proj team oriented on role, responsibilities, authority, value of SQA.	1.A SW CCB exists 2.A proj SCM group exists 3. Adequate resources 4. Adequate training-SCM 5. Adequate training-SW eng group
Activities performed	1.Review Sys Reqt allocated to SW (i.e. B/L) 2.Use Sys Req B/L as basis for SW development (plans, work products, activities) 3.Review & incorporate changes to Sys Req B/L.	1.SW eng. in proposal prep. 2.Early SW project plan'ng 3.SW eng in overall plan'ng 4.Sen mgt review ext cmts 5.Define SW lifecycle 6.Dev. SDP per doc. proc. 7.Document SDP 8.Identify controlling items 9.Estimate size of items 10.Estimate effort & cost 11.Est. computer resources 12.Derive SW schedule 13.Identify risks 14.Plan support environ't 15.Record planning data	1.Follow/Use SDP 2.Revise SDP per doc proc. 3. Sen mgt review ext cmts 4.Communicate changes 5. Track size of items 6. Track effort & cost 7. Track comp. resources 8.Track schedule 9. Track tech activities 10.Track risks 11.Record mgt data 12.Conduct int. reviews to track progress 13.Perform formal reviews at selected milestones.	1.Work to be subcontracted is defined & planned per a documented procedure 2.Pick contra'r per doc proc 3.Ag't is basis for cont mgt 4.Rev/Appr've subcont SDP 5. Track vs subcont SDP 6.Mge change per doc proc 7.Hold reviews/status mtgs 8.Hold tech reviews/comms 9.Hold formal reviews 10.Prime QA monitor sub-contractor's QA activities 11.Monitor sub-CM activ'ty 12.Conduct acc. testing 13.Evaluate sub-perfor'nce	1.Prepare SQAP 2. Follow/Use SQAP 3.SQA participates in prep/review of SDP, stds, procedures 4.Review SW eng activities for compliance 5.Audit designated work products for compliance 6.Periodically report results to SW eng group 7.Document & handle deviations in activities and work products 8.SQA reviews its activities with customer QA	1.Prepare SCMP 2. Follow/Use SCMP 3.Establish CM library sys. 4.Identify CIs 5.Implement PRACAS 6.Control b'line changes 7.Products from the SW baseline library are created & their release is controlled according to a documented procedure 8.Record status of SCIs 9.Standard reports of SCM activities & SW baseline contents are circulated 10.Audit SW baseline
Measurement & analysis	1.Make measurements & use them to determine B/L status.	1.Make measurements & use them to determine SW planning status.	1.Make measurements & use them to determine SW tracking/oversight status.	1.Make measurements & use them to determine sub-contract mgt status.	1.Make measurements & use them to determine cost & schedule status (of QA)	1.Make measurements & use them to determine sub-SCM status.
Verifying implementation	1.Sen Mgt review B/L mgt 2. Proj Mgt review B/L mgt 3. QA review B/L mgt	1.Sen Mgt rev. plan act'y 2. Proj Mgt rev. plan act'y 3. QA rev. SW plan activity	1.Sen Mgt rev. track act'y 2. Proj Mgt rev. track act'y 3. QA rev. SW track act'y	1.Sen Mgt rev. sub-c act'y 2. Proj Mgt rev. sub-c act'y 3. QA rev. sub-c act'y	1.Sen Mgt rev. QA act'y 2. Proj Mgt rev. QA act'y 3.Indep. experts rev. QA act'y	1.Sen Mgt rev. SCM act'y 2. Proj Mgt rev. SCM act'y 3.SCM group audits b'lines 4.QA rev. SCM act'y

3. CMM Level 3 - Defined

KPA ->	Organisation Process Focus	Organisation Process Defn.	Training Program	Integrated SW Management	SW Product Engineering	Intergroup Coordination	Peer Reviews
Goals	1.Coordinate SW process defn & improv't 2.Identify strengths & weaknesses vs a Std 3.Plan dev. & improv't	1. <u>A std SW process</u> for the organisation is developed/maintained 2.Info related to use of std SW process by proj's is generated/circulated	1.Plan training activiti's 2.Provide training re SW management & technical roles 3. SW engineers etc get necessary training	1.A project's defined SW process is a tailoring of the std process 2.Plan & manage project per project's defined SW process	1.SW eng tasks are defined, integrated and consistently performed 2.SW work products are kept consistent with each other	1.Customer's reqts agreed by all affected groups 2.Agree inter-engineering group commitments 3.Mge inter-group issu's	1.Peer review activities are planned 2.Defects in SW work products are identified & removed.
Commitment to perform	1.Follow written policy 2.Sen mgt sponsors 3.Sen mgt oversees	1.Follow written policy for dev'ing/main'g a std SW process & assets	1.Follow written policy for meeting training needs.	1.Follow written policy for ... using org's std SW process	1.Project follows a written org. policy for performing SW eng	1.Proj follows a ... policy for establishing inter-disciplinary teams	1.Proj follows a written org. policy for performing peer reviews
Ability to perform	1.Group responsible for org. SW process exists 2.Adequate resources 3.Adequate training 4.Orientation provided	1. Adequate resources are provided for developing/maintaining a std SW process & assets 2. Adequate training	1.Group responsible for training exists 2.Adequate resources 3.Trainers have skills 4.Orient SW managers	1.Adequate resources 2. Adequate training in tailoring std SW proc. 3. Adequate training in applying proj's process	1.Adequate resources 2. Adequate training 3.Orientation in related SW eng disciplines 4.Orientation for mgrs	1.Adequate resources 2.Compatible sup. tools 3.Teamwork mgt train'g 4.Orient to other groups 5.Orient to teamwork	1.Adequate resources 2. Adequate training for peer review leaders 3. Adequate training for peer review participants
Activities performed	1.Assess SW processes periodically & develop action plans to address the assessment findings 2.Dev & Maintain plan 3.Coordinate activities 4.Coordinate use of SW process database 5.Monitor new elements in limited use & transfer if appropriate 6.Coordinate training 7.Inform implementors of process dev & imp.	1. Develop & maintain std SW process per documented procedure 2.Document org. std SW process 3.Approved SW life cycles are documented & maintained 4. <u>Tailoring guidelines</u> are docum'ed & maint'd 5.Establish/Maintain SW process database 6.Establish a library of SW process material	1.Each SW project develops & maintains a training plan 2.Org training plan is developed & maintain'd 3.Training is provided per org training plan 4.Training courses are prepared per standards 5.Establish a waiver procedure (if individuals already have skills) 6.Maintain training records	1.Tailor std SW process 2.Revise proj defined SW process per proc. 3.Develop/Maint'n SDP 4.Manage per project's defined SW process 5.Use SW process DB 6.Manage items' size 7.Manage effort & cost 8.Manage critical comp-uter resource usage 9.Mge critical path etc 10.Manage risk 11.Review progress	1.Approp. SW eng methods & tools in proj defined process 2.SW reqt process 3.SW design process 4.SW code process 5.SW testing is in accordance with project defined SW process 6.Integrat'n test process 7.Sys & Acc test proc. 8.Prepare maint'nce docs 9.Gather/anal. defect inf 10.Consist'ncy/Tracing	1.Diff groups & customer establish Sys Reqts 2.Groups monitor & coord. activities/issues 3.Use a documented plan for inter-group comms/tracking/etc 4.Manage critical intergroup dependencies 5.Work products for other groups are reviewed by them 6.Unresolv'bles by proc 7.Tech reviews/comms	1.Peer reviews & the plans are documented 2.Peer reviews are performed according to a documented procedure 3.Data on the conduct and results of the peer reviews are recorded
Measurement & analysis	1.Make measurements & use them to determine dev/imp status.	1.Make measurements & use them to determine definition status.	1.Make meas'ts-use to determine train'g status. 2.Measure for quality	1.Make measurements determine effectiveness of int. SW mgt activiti's	1.Measure/Determine Functionality & Quality 2.Measure status	1.Make measurements .. determine status of intergroup coordination	1.Make measurements .. determine status of peer review activity
Verifying implementation	1.Sen Mgt review SW process dev/imp activities	1.SQA review activities & work products for develop'g & maintain'g std SW process/assets	1.Sen Mgt review 2.Indep. evaluation for relevance, consistency 3.Review or audit	1.Sen Mgt rev PM acts. 2. Proj Mgt rev PM acts 3. QA review PM activities & work prods.	1.Sen Mgt review 2. Proj Mgt review 3. QA review/ audit activities/work products	1.Sen Mgt review 2. Proj Mgt review 3. QA review/ audit activities/work products	1. SW QA review/audit activities/work products

4. CMM Level 4 - Managed AND CMM Level 5 - Optimizing

KPA ->	Level 4		Level 5		
	Quantitative Process Management	Software Quality Management	Defect Prevention	Technology Change Management*	Process Change Management*
Goals	1. Plan quant. proc. mgt activities 2. Control process performance of project's defined SW process quantitatively 3. Process capability of organisation's std SW process is known quantitatively	1. Plan project QM activities 2. Define measurable goals 3. Quantify and manage actual progress toward achieving the quality goals for the SW products	1. Defect prevention activities are planned 2. Common defect causes are sought out & identified 3. Common causes of defects are prioritised & eliminated	1. Incorporation of technology changes is planned 2. New technologies are evaluated to determine their effect on quality & productivity 3. Appropriate new technologies are transferred to normal practice	1. Continuous process improvement is planned 2. Participation is organisation-wide 3. Org's standard SW process & project's defined SW processes are improved continuously
Commitment to perform	1. Follow written policy for measuring/quant. controlling project's defined SW process 2. Written policy for analysing proc capability of org's std proc	1. Follow written policy for managing SW quality	1. Org. follows written policy for defect prevention activities 2. Project follows written policy for defect prevention activities	1. Org. follows written policy for improving its technology capa'ty 2. Sen mgt sponsors tech change activities 3. Sen mgt oversees tech change	1. Org. follows written policy for implementing SW process improvements 2. Sen mgt sponsors SW process improvement activities
Ability to perform	1. Responsible group exists 2. Adequate resources, funding 3. Support to measure & analyse 4. Adequate trai'g of resp. people 5. Orient affected groups, people	1. Adequate resources, funding 2. Adequate training of responsible people 3. Members of SW eng & other related groups get SQM training	1. Responsible group exists in org 2. Responsible team exists in proj 3. Adequate resources, funding at org & project levels 4. Training provided	1. Responsible group exists in org 2. Adequate resources, funding 3. Support for data coll'n/analysis 4. SW proc data available to anal. 5. Training provided	1. Adequate resources, funding 2. SW mgrs receive SPI training 3. SW eng people get SPI training 4. Sen mgt get SPI training
Activities performed	1. Develop SW project's plan for quantitative process mgt per proc 2. Perform activities per plan 3. Based on the project's defined SW process, determine strategy for data collection & analysis 4. Collect control data per proced. 5. Anal/Control proj def. SW proc 6. Reports prepared/circulated 7. Est/Ma'n b'line for std SW proc	1. Develop/Maintain project's SW Quality Plan per document'd proc 2. Project's SW quality plan is basis for project's SQM activities 3. Define/Monitor/Revise project quantitative quality goals 4. Measure, analyse & compare achieved quality vs quality goals 5. Allocate project's quant. quality goals approp. to subcontractors	1. Project develops/maint's a plan 2. At SW task start, hold prep mtg - task & related defect activities 3. Conduct causal analysis mtgs 4. Defect prev. teams meet perio'ly 5. Doc'nt/Track defect prev data 6. Incorporate revs to std SW process per procedure 7. As 6 for project's def. SW proc. 8. Provide feedback generally	1. Org. develops/maint's a plan 2. Group resp. for org's tech change mgt works with projects 3. SW mgrs, tech staff informed 4. Group for tech change analyses std SW process to improve. 5. Select, acquire tech per proced. 6. Pilot efforts are conducted 7. Incorpor'te new tech in std proc 8. As 7 for proj's defined process	1. Establish an SPI program 2. Resp. group coordinates SPI 3. Resp. group devs/maints plan 4. SPI activities are per plan 5. SPI proposals handled per proc. 6. Org members participate in SPI 7. Install pilot SPI's if approp. 8. Implement an SPI per proced'e 9. Records kept of SPI activities 10. Provide feedback generally
Measurement & analysis	1. Make measurements determine status of quan proc mgt activities	1. Make measurements determine status of SQM activities	1. Make measurements determine status of defect prevent. activities	1. Make measurements determine status of tech. change manage'nt	1. Make measurements determine status of SPI activities
Verifying implementation	1. Sen Mgt review 2. Proj Mgt review 3. SW QA review/ audit	1. Sen Mgt review 2. Proj Mgt review 3. SW QA review/ audit	1. Sen Mgt review 2. Proj Mgt review 3. SW QA review/ audit	1. Sen Mgt review 2. SW QA review/ audit	1. Sen Mgt review 2. SW QA review/ audit

* Organisations will often have to address these types of issues even if the organization is otherwise at a lower CMM level.