A QUESTIONNAIRE BASED METHOD FOR CMMI LEVEL 2 MATURITY ASSESSMENT

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ABSTRACT
CMMI has gained widespread acceptance as a viable software process assessment model. In this study, we take up CMMI, and consider the first maturity level or level 2 of the model for companies new to CMMI or just beginning to adopt CMMI in their process improvement efforts. A questionnaire based assessment method was developed primarily intended to be facilitate quick assessment or self assessment of CMMI maturity level 2 of a software company. The questionnaire can also be used for process improvement purposes. The paper reports on the results of conducting the questionnaire at five software companies and discusses its value as an indication of maturity at level 2 of CMMI and draws conclusions.

Keywords: *Software Quality, CMMI, Process Improvement, Maturity Models, Process Appraisal.*

CMMI 2. DÜZEY OLGUNLUK DEĞERLENDİRMESİ İÇİN ANKET TABANLI BİR YÖNTEM

ÖZET
CMMI, geçerli bir yazılım süreç değerlendirme modeli olarak yaygın kabul görmektedir. Bu çalışmada, CMMI ele alınmakta ve kendi süreç iyileştirme çalışmalarında CMMI' a yeni veya henüz adapte olmaya başlayan firmalar için modelin birinci veya ikinci olgunluk düzeyi göz önünde bulundurulmaktadır. Öncelikli olarak bir yazılım firmasının hızlı değerlendirme yapması veya kendi CMMI 2. düzey olgunluk değerlendirmesini kolaylaştırması için bir anket tabanlı değerlendirme metodu geliştirilmiştir. Aynı zamanda bu anket süreç iyileştirme amaçları için de kullanılabilmektedir. Makale, 5 yazılım firmasında yürütülen anket sonuçlarını vermektedir. CMMI 2. düzey olgunluk göstergesi olarak bu anket değerleri ele alınmakta ve sonuçlar ortaya konulmaktadır.

Anahtar Kelimeler: *Yazılım Kalitesi, CMMI, Süreç İyileştirme, Olgunluk Modelleri, Süreç Değerlendirme*

1. INTRODUCTION

The information revolution of the late 20th century has brought software to the core of all business activities. As business competition grows, the importance and the need for advanced, complex, as well as high quality software systems become vital. Quality has always been elusive [1]. In general the two ways to achieve quality in a product are the proactive or process based approach and the reactive or testing based approach [2]. Often it is a well accepted fact odologies, highlights both the advantage and the necessity for companies producing software. In recent years, several models have been developed to evaluate

that the quality of a product is largely determined by the processes used in the development and the production of the product. Therefore, a process-focused quality approach has come to dominate the software industry rather than a product focused quality management.

A product or service provided to customers is the output of managed processes. Process management based thinking and the use of meth

the quality systems and processes used in software development, to provide an indication for software process quality. The models are also used, to improve

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the processes and to appraise maturity/capability level of a software producing organization. Several models have been developed concerning software process quality, chiefly CMM, CMMI, and ISO 15504, also known as software process appraisal or assessment models.

The most widely used of these models at the present is CMMI, which can be used for process improvement and maturity/capability determination. Although CMMI is supposedly applicable for all sizes of companies, it can be rather costly for smaller companies and/or difficult to understand and implement in practice. It is also known that the software industry in most countries is made up mainly of small and medium size companies [3]. It has been the objective of this study to devise a simple method which would be desirable for such companies to step into the world of CMMI by assessing their maturity at the beginning level or level 2.

We first briefly review the structure of the CMMI model together with a discussion of the meaning of the first step up in maturity improvement. That is, moving up from the entry level (initial level or level 1 in CMMI terms), to the first level of maturity, which is level 2 or the so called performed level. Next we propose a questionnaire based method developed for a quick and easy indication of whether a company has achieved level 2 or not. We report on the results of administering the method to five software companies and conclude with a discussion.

2. CAPABILITY MATURITY MODEL INTEGRATION (CMMI)

Capability Maturity Model Integration (CMMI) Model was developed and first introduced in 2001 with version 1.0, by Carnegie Mellon University, Software Engineering Institute (SEI) as sponsored by the U.S. Defense Department. It was based on the original CMM model which was developed and introduced in the late 1980s continuing in use up through the turn of the century. CMMI integrated the original CMM or software CMM (SW-CMM) with the CMM models on system engineering (SE-CMM) and on integrated product development (IPD-CMM). These and other CMM models have proved useful for many organizations but the differences among these models were causing problems of compliance and diverging directions in focusing on improvements.

Another important feature of the CMMI model over the CMM model is the introduction of continuous representation which enables the option of assessing and grading each process individually with a process capability level. Furthermore, the concept of continuous representation which was a central concept in the ISO 15504 (SPICE) model, allows CMMI to be

ISO 15504 compatible, a feature important for the international community.

Software Engineering Institute (SEI) has accepted as a basic principle for process management, that *"the quality of a system or product is highly influenced by the quality of the process used to develop and maintain it"*. Another basic principle is that the capability of a company to produce software successfully depends on its maturity, which can be measured using the methods provided in the model as maturity levels. Each maturity level considers a given group of processes or process areas. Achievement of a capability level in those process areas, as elaborated in the model, grants that particular maturity level to the organization.

CMM, CMMI, and similar process capability models have been long studied. Many papers have reported the costs and benefits [4] [5] to organizations of using process capability models for Software Process Improvement (SPI), including intangible benefits [6] [7]. Some earlier papers have discussed organizational motivations for adopting these approaches [8].

2.1 The Structure of CMMI

CMMI has identified 22 process areas, or PAs, which have to be managed well for successful software development. These PAs are in turn treated within two representations of the model, which are the staged representation and the continuous representation. Staged representation treats the software producing organization as a whole, in terms of maturity levels which range from level 1 to level 5. In the continuous representation, each PA is handled on its own in terms of a process capability level which ranges from 0 to 5. The organizational maturity levels and the process capability levels are given the names as in Table 1.

Table 1. Capability and Maturity Levels of CMMI

Levels	Continuous Representation Capability Levels	Staged Representation Maturity Levels
Level 0	Incomplete	N/A
Level 1	Performed	Initial
Level 2	Managed	Managed
Level 3	Defined	Defined
Level 4	Quantitatively Managed	Quantitatively Managed
Level 5	Optimizing	Optimizing

Each representation has its advantages and situations for suitable applicability [9]. The staged representation is suitable for an organization that does not emphasize one process over another, but needs an overall guidance for improvement, or an organization in need of producing an indication or proof of its general level of maturity. The latter situation may be required as a

precondition to enter a bidding process in some country or organization.

The continuous representation provides flexibility for selecting the processes considered important for achieving the business goals of the organization, as the organization best sees fit for the situation [10]. It allows the measurement of improvement at the process level. This finer level of assessment enables better monitoring of process improvement by upper management.

The two representations are not independent. They are based on the same 22 process areas, and there is a transformation or mapping from the continuous representation to the staged representation, known as equivalent staging. If a company achieves certain capability levels in certain PA's, then it is automatically assumed to obtain certain maturity levels. Figure 1 gives that mapping from one representation to the other.

A process area means a c1uster of related practices in an area that, when implemented collectively, satisfies a set of goals considered important for making a significant improvement in that area [9] [10]. The 22 process areas of CMMI are given in Figure 1 with their names and abbreviations.

CMMI gives each process area some goals which have to be satisfied to achieve certain capability levels for that process. Goals come in two types, as specific goals and generic goals. Specific goals are unique to each process area, whereas the same generic goals apply to all process areas. A specific goal describes the unique characteristics that must basically be present to satisfy the particular process area A generic goal describes the characteristics that must be present to institutionalize the processes that implement a process area [9] [10].

Every goal has a number of practices which are normally expected to be implemented and exercised, if the goal is to be achieved. Thus generic goals have generic practices and specific goals have specific practices. A generic practice is the description of an activity that is considered important in achieving the associated generic goal. A specific practice is the description of an activity that is considered important in achieving the associated specific goal [9] [10]. Practices have subpractices in a further refinement of the model.

Name	Abbr	ML	CL1	CL2	CL3	CL4	CL5
Requirements Management	REQM	2					
Project Planning	PP	2					
Project Monitoring and Control	PMC	2					
Supplier Agreement Management	SAM	2	*Target Profile 2*				
Measurement and Analysis	MA	2					
Process and Product Quality Assurance	PPQA	2					
Configuration Management	CM	2					
Requirements Development	RD	3					
Technical Solution	TS	3					
Product Integration	PI	3					
Verification	VER	3					
Validation	VAL	3					
Organizational Process Focus	OPF	3		*Target Profile 3*			
Organizational Process Definition + IPPD	OPD + IPPD	3					
Organizational Training	OT	3					
Integrated Project Management + IPPD	IPM + IPPD	3					
Risk Management	RSKM	3					
Decision Analysis and Resolution	DAR	3					
Organizational Process Performance	OPP	4	*Target Profile 4*				
Quantitative Project Management	QPM	4					
Organizational Innovation and Deployment	OID	5	*Target Profile 5*				
Causal Analysis and Resolution	CAR	5					

Key: Name = the full name of the process area.
  Abbr = the acronym that corresponds to the Name.
  ML = the maturity level assignment of the process area in the staged representation.
  CL1, CL2, CL3, CL4 and CL5 are capability levels in the continuous representation.

Figure 1. Target Profiles and Equivalent Staging [9]

2.1.1 Staged Representation

The staged representation of CMMI is divided into five maturity levels (MLs) which are:
- initial (ML 1),
- managed (ML 2),
- defined (ML 3),
- quantitatively managed (ML 4), and
- optimizing (ML 5)

The 22 process areas are organized into these five maturity levels in the staged representation, meaning that to achieve a particular maturity level, the organization must pass certain criteria in all the process areas of that maturity level and the levels below, as given in the mapping of Figure 1.

In the staged representation, maturity levels provide a recommended order for approaching process improvement. The maturity levels of an organization are measured by the achievement of the specific and generic goals that apply to each set of process areas. The staged representation describes the evolution of improvements to the software development process, beginning with basic improvement practices and progressing through a predefined and proven set of successive levels [11].

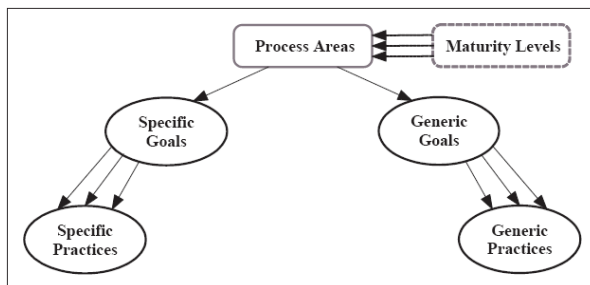In Figure 2, the structure of the staged representation of CMMI is shown.

Figure 2. The Staged Representation [9]

2.1.2 Continuous Representation

The continuous representation of a CMMI model consists of the same process areas as the staged representation. However, no process area is assigned to a particular maturity level.

In the continuous representation, every process is placed in one of four process area categories. These process area categories are: process management, project management, engineering, and support.

The continuous representation uses six capability levels (CLs) to measure the achievement of a specific process area for an organization. These are:
- incomplete (CL 0),
- performed (CL 1),
- managed (CL 2),
- defined (CL 3),
- quantitatively managed (CL 4), and
- optimizing (CL 5)

A capability level consists of related specific and generic practices for a process area that can improve the organization's processes associated with that area. Capability levels build on one another, providing a recommended order for process improvement. The continuous representation gives software organizations the flexibility to select process areas they want to improve, enabling them to select the order that best meets their business objectives [11]. The structure of the continuous representation of CMMI is shown in Figure 3.
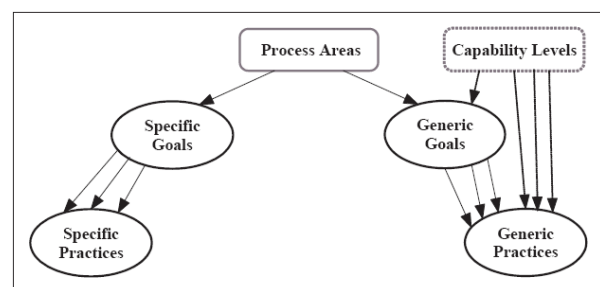

Figure 3. The Continuous Representation [9]

2.2 CMMI Evaluation

An organization that wants to improve its software process quality has to examine closely the procedures for appraisals and audits. The reported result of the current situation of an organization is called an appraisal, but to be an audit, the appraisal must be done by an independent person or group outside of the organization [12]. The appraisal report is a document, which among other things, lists the strengths and weaknesses of the organization which wants to reach a desired process capability level or a maturity level. It is a guideline to plan improvement efforts, and a document to track the developments and achievements. The preparation of this report, forms the basis of process improvement plans, and is very important [9] [12].

There are three classes of CMMI appraisal: A, B, and C as shown in Table 2. Class A appraisals are costly, time-consuming, and resource-intensive, but provide the highest levels of assurance about their findings. Class B appraisals are less costly, time-consuming and resource-intensive as they use fewer appraisers, appraise fewer projects, and rely on fewer forms of evidence. Class C appraisals have the lowest cost and are easiest to perform, and can approach the simplicity of a structured questionnaire. All appraisals result in a report of findings about an organization's capability, but only Class A appraisals can result in a publicly-

reportable "rating" of the organization's CMMI maturity level [6].

Table 2. Appraisal Class Characteristics [13]

Class of Appraisal	A	B	C
Size of appraisal team	8-10	3-4	1-2
Appraisal time	10 days	3-4 days	1-2 days
Minimum #of data collection methods	3	2	1
On-side interview required	Yes	Yes	No
Coast	High	Medium	Low
Intrusiveness	High	Medium	Low
Validity	High	High	Low
Reliability	High	Medium	Low

3. A METHOD FOR CMMI LEVEL 2 SELF ASSESSMENT

In this section, a method is proposed to evaluate software organizations, have process focused quality management concept, whether they are enough or not.

3.1 The Rationale

Software companies may have two basic reasons to have a CMMI appraisal. First, the company may be required to produce an official appraisal document as a requirement to submit a bid in some project tender. Second, as is more often the case, a company wants it primarily as a benchmark to compare itself with a world standard and as a yardstick in their process improvement efforts. The latter is often an internal, perhaps confidential operation of the company until they are ready and confident for a full blown official CMM Class A appraisal.

However, a full official Class A CMMI appraisal is a rather expensive operation which also takes the time of several employees over several days. In fact the reason for Class B and Class C appraisals is rather a preparation for the "ultimate" Class A appraisal.

Therefore, companies would like some easier, less costly and less time consuming method indicating their CMMI maturity. This is especially true for smaller companies which are getting their first introduction to CMMI. The questionnaire based method reported in this paper has been motivated by this need. Assessment techniques have been used before based on questionnaires and pro-forma schemes [14]. In our case a set of questions were developed with the purpose of a fairly easy and more or less reliable way of indicating whether a company meets the requirements of CMMI maturity level 2.

A total of 39 questions were formulated put forth to cover the seven process areas of CMMI maturity level 2. The process areas and the number of questions for each are given below:

- REQM (Requirements Management)   : 3 questions
- PP (Project Planning)   : 9 questions
- PMC (Project Monitoring and Control)   : 5 questions
- SAM (Supplier Agreement Management)   : 4 questions
- MA (Measurement and Analysis)   : 5 questions
- PPQA (Process and Product Quality Assurance)   : 5 questions
- CM (Configuration Management)   : 8 questions

The number of questions was not determined beforehand. The numbers do not reflect so much the importance of each process area, but are a result of covering the range of practices by as few questions as possible and still remaining fairly comprehensive and reliable.

There were five possible answers to each question, each answer receiving points as shown below:

Choice of answers:		Points received:
• definitely yes	=	4 points
• usually	=	3 points
• planned but not applied	=	2 points
• not sure	=	1 point
• definitely no	=	0 point

Each answer received a 0 to 4 point grade, as also shown above. The questions were so constructed that more points always contributed positively to higher maturity. Seven questions are given below as a sample set one from each process area:

- Do you provide double-sided traceability on the requirements?
- Do you estimate size, effort, and cost for software projects?
- Are the commitments and project risks being traced according to project plan?
- Do you determine the methods to be used in the purchasing of a product and product components?
- Are you giving a course to the people regarding statistical methods, data collection, analysis and reporting processes?

- Do you have any quality assurance activities for software projects?
- Do you have any general configuration management policy of the institution?

3.2 Application of the Questionnaire

The questionnaire was administered in five Turkish software companies. The companies were visited at an appropriately high level which was often the general manager. A responsible and knowledgeable person was identified who answered the questions posed, sometimes referring to his colleagues or other employees in the company. The interviews usually took about 1 and a half hours. These companies have all claimed to have adopted a process approach to achieving quality, some rather recently, some for a longer time. Table 3 below shows the years the companies were established and the number of employees they had at the time of conducting the questionnaire:

Table 3. The year of organization and the number of workers of appraised

The Organization	The Year of Organization	The Number of Workers
The Organization A	2002	14
The Organization B	1992	15
The Organization C	1990	20
The Organization D	1984	260
The Organization E	1996	90

The answers of each company to the questions in a process area were averaged. Table 4 below shows the average points received by each company in each process area. Remembering that figures can have a maximum value of 4 and a minimum value of 0, the maximum total score over all seven areas is 7*4=28. Table 4 also gives the total for each company and the final score which is the ratio of the total to the maximum possible average score of 28 expressed as a percentage.

Table 4. The average points received by each company in each process area.

CMMI Level2 Processes	Organizations				
	Org. A	Org. B	Org. C	Org. D	Org. E
REQM	1.67	3.00	2.33	3.33	3.00
PP	2.78	1.67	2.44	3.22	3.56
PMC	2.80	3.00	3.00	3.80	3.00
SAM	1.00	1.50	1.00	3.75	4.00
MA	0.60	2.40	2.40	3.60	2.80
PPQA	2.00	0.20	0.20	3.80	2.80
CM	0.88	1.00	2.00	3.75	2.63
Total	11.73	12.77	13.37	25.25	21.79
Final Score (%)	42	46	48	90	78

According to linear weighted method, the organization D provides CMMI Level 2 shown in Table 5. According to their speech, they already provide CMMI Level 3. So it shows us that our method is compatible with the real situation. The organization E provides CMMI Level 2 partially. In other words, it will able to provide CMMI level 2 with a small effort. We can't say that the other organizations A, B, C provide CMMI Level 2. These organizations have to control their processes again and they have to create a quality assurance system in their structures.

4. RESULTS

The results are given in Table 4. They show three companies with similar scores and two companies with much higher scores than the first three. Company D clearly has the highest success rate. It was learned during the question and answer session that the company in fact had a consultant on CMMI who had conducted his own evaluation with the result that not only a maturity rating of 2 was warranted, but

moreover the company was within reach of a maturity level of 3. Further assessment of company E by the authors indicated that maturity level of 2 was attainable with a little more effort. In fact, company E was planning to hire a consultant for process improvement regardless of any CMMI rating to work for. Talks with companies A, B and C showed that they were not concerned with institutionalizing process improvement. They depended more on the capability and knowledge of certain individuals, some having been with the company since establishment. Further assessments of companies A, B and C, showed that they were some distance away from attaining a level 2 maturity. Although they admit that they need to better define and establish their basic processes, they were not considering any disciplined way of following a model like CMMI.

Another interesting and perhaps expected result was the correlation between the number of employees and the final score. Companies with 15 or 20 employees were far off from achieving a maturity level of 2,

whereas a company with 260 employees was there. Company E with its 96 employees was also well within reach of the maturity level 2 if not already there.

5. CONCLUSION

A questionnaire method was developed to make rather quick and easy assessment of their level of achieving CMMI maturity level 2. The method is especially meant to be used by smaller organizations being newly introduced to CMMI, for quick self assessment of whether level 2 has been achieved or not.

The method was applied with five software companies in Turkey. The results show that the method can be used for the purposes stated. A threshold can be put at a score of about 80% to indicate success. The method is not concerned at all with higher levels. A high score has no implications for levels 3 and above. However, a score of 80 or better, most likely indicates having achieved the maturity level 2.

The results also reinforce the belief that size of a software company is a major factor in its ability to achieve higher levels in the CMMI maturity ladder.

It cannot be claimed that this is an absolutely reliable method, but it is believed to be a reliable indication. No claim is made that it can represent or substitute for an official CMMI appraisal. It does carry a utility though for small and midsized companies, which have a hard time affording to hire consultants or start internal process improvement programs, but want to get a foot in the door to using CMMI eventually, both for process improvement and to get an official appraisal when they think is the right time.

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