Software Process Improvization Framework using Fuzzy Logic Based Approach for Indian Small Scale Software Organizations

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ABSTRACT
In this paper, the researchers describe the results obtained after assessing the software process activities in five small to medium sized Indian software companies. This work demonstrates a cost effective framework for software process appraisal, specifically targeted at Indian software Small-to-Medium-sized Enterprises (SMEs). The framework explicitly focuses on organizations that have little or no experience in software process improvement (SPI) programmes. The companies involved in this assessment have no CMMI experience prior to the work. For Indian software SME's, it has always been difficult to find the resources, both time and money, which are necessary to engage themselves properly in SPI. To alleviate this, we have developed a low-overhead and relatively non-invasive solution tool to support SMEs in establishing process improvement initiatives. The paper initially describes how the framework was developed and then illustrates how the method is currently being extended to include a questionnaire based approach that may be used by the appraised organization to perform follow-on self-assessments. The results obtained from this study can be used by organizations to achieve the CMMI standards. Finally, the results are discussed for consistency by incorporating a scientific based approach to avoid ambiguities which arise while arriving at a result.

Keywords:
Software Process Improvement (SPI), Self-Assessment, Capability level, Indian SMEs, Software Process Assessment, Fuzzy logic.

1. Introduction

The Software Industry in India plays a prominent role in the Indian Economy. As per a report given by NASSCOM CEO Summit in the year 2008, 85% members of NASSCOM are SMEs. They generated revenue of about US $12-15B in software exports in the year 2008. Around 96% of Indian software SMEs supported to run 23 million businesses in US, which generate 64% of new employment. Typical Indian software SME will have revenue less than Rs.100 million[2]. During the late nineties, the SPIRE (Software Process Improvement in Regions of Europe) programme applied the SPICE model to a variety of SMEs[5]. However, the research indicates that only a small percentage of Indian indigenous software development companies have implemented formal SPI assessment methods. One such study emphasizes that the Indian software companies are reluctant to engage in formal SPI assessments because of the high cost and resources involved. The findings of literature survey showed that Indian software SMEs are employing fewer than 20 people.

Many Indian SMEs compete with big organizations for project from prospective clients[3]. One of the major problems faced by the Indian software SMEs is the lack of process assessment or process improvement activities that are carried out in big organizations, which not only help to improve the project standard but also to minimize the time, labor and fiscal budget of the project.

Small companies give little importance to these activities; one employee plays multiple roles in the company, for example a programmer might play the role of a technical architect, developer and tester simultaneously. This scenario is quite common in an SME environment[6]. This not only affects the quality of work but also the impact and significance of the project. Many of the smaller companies oppose the standards due to the expensive compliance effort, both in time and money. Some of the shortcomings faced by SMEs are:

- Excessive documentation.
- Extensive number of Specific Practices (SP).
- Requirement of extensive resources.
- High training costs.
- Practices independent of project type.
- Lack of guidance in satisfying project and development team needs.
- Many of the smaller companies oppose the CMMI model due to the expensive compliance effort, both in time and money[1, 4].

In this paper, we present a method to assess the software process activities of Indian small – medium sized software organization that is not planning to adopt SPI activities, but considers itself to be successful in terms of meeting customer and company needs.

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2. Literature Review

In order to understand the current assessment techniques which are adopted by the Indian SME's, a literature survey was performed with preliminary results obtained from Indian software market. At the end of our literature survey we found the companies adopt assessment methods based on[5]

i. ISO/IEC 15504
ii. CMM/CMMI

2.1 Issues involving Process Improvement in Small Business Environment

A small company, desiring to implement process improvement program, is faced with becoming less competitive in terms of overhead rate, not only with other small companies that may not be paying for process improvement programs, but also with large companies whose overhead rates are not substantially affected by their software process improvement programs. Small companies are now frequently competing with large businesses for small contracts, and they fear that their competitive advantage of lower overhead rates will be lost when paying for software process improvement programs[3]. Further compounding the problems of small businesses trying to implement a CMMI-based process improvement program is the fact that many of the practices within the CMMI are not applicable to small projects, which are prevalent in small businesses. The businesses fear that the money spent on software process improvement will not enable them to satisfy contract maturity requirements
The research work carried out in SPI activities for Indian Software SME's environment is very less in number. Hence our work took an initiative step to fill the gap in this area.

3. Framework

Our framework is a collection of questionnaire and fuzzy logic toolbox. The main advantage of the framework is that additional process areas can be accommodated in future with minor changes. CMMI-Dev v1.2 was taken as the model for assessment. It was represented in two ways namely, staged and continuous as in table 1[7]. Continuous representation suits and so was adopted for our assessment of SMEs. Out of 22 process areas in continuous representation, we took 13 process areas for study. These process areas satisfy all the organizations' business goals which are considered primary requirements for assessment.

In order to mitigate the software process improvement problem the framework was designed, and tested in 5 various Indian software SMEs in two major states of India. It helped us to identify the weak areas of an organization and suggest what approach or activity will lead to improvement. Five small software organizations with respective employee strength are given in table 2.

Table 1 - Capability and Maturity Levels of CMMI[7]

Levels	**Continuous representation capability level**	**Staged representation Maturity level**
0	Incomplete	N/A
1	Performed	Initial
2	Managed	Managed
3	Defined	Defined
4	Quantitatively Managed	Quantitatively Managed
5	Optimizing	Optimizing

Three trials were carried out in the organizations to find out the weak areas and to assess the maturity level of each organization. This was done by measuring the capability level of each process area.

Table 2 – Organization and Number of Employees

Organization	**Employee strength**
A	10
B	49
C	30
D	37
E	49

Further suggestions were given to improve the maturity level. The first trial helped to identify the weak areas and suggestions were given for the process improvement. The second trial carried out after two months reflected the impact of the first trial .The third trial carried out after three months revealed the performance improvement after

the implementation of the framework. Figure 1 shows overall activities of framework.

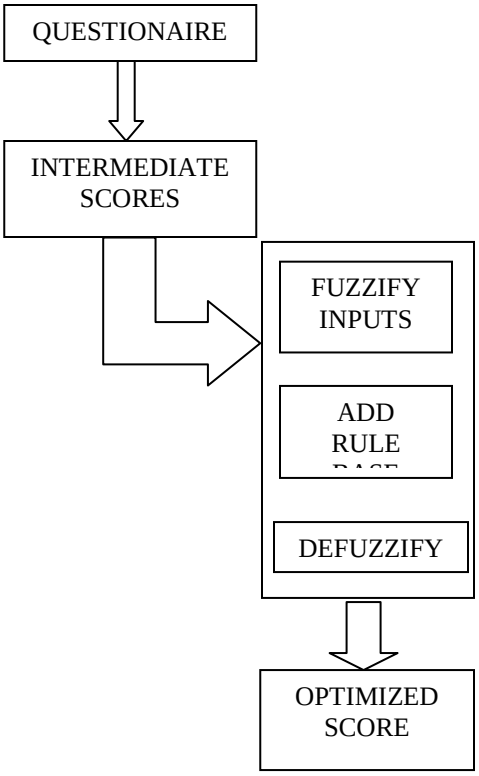


Figure 1 : Block Diagram of the framework

3.1 Tool used for evaluation

Extended Maturity questionnaire was used as the tool for carrying out the assessment. SCAMPI is a common appraisal and assessment method. A person trained and certified in SCAMPI is essential to carry out the assessment. It is an overhead to the organization. Extended maturity questionnaire is an inexpensive tool that was used to collect data. The collected data was processed and analyzed to find out the results.

A total of 50 questions were formulated to cover the 13 process areas. The process areas and the number of questions raised are given below.

Project Management:
Project Planning (PP) : 4 questions
Project Monitoring and Control (PMC) : 4 questions
Risk Management (RSKM) : 4 questions
Engineering:
Requirements Management (REQM) : 4 questions
Requirements Development (RD) : 4 questions
Technical Solution (TS) : 4 questions
Verification (VER) : 4 questions
Validation (VAL) : 4 questions
Product Integration (PI) : 3 questions
Process Management:
Organizational Training (OT) : 4 questions
Organizational Process Definition + IPPD (OPD) : 3 questions
Organizational Process Focus (OPF) : 4 questions
Support:
Process and Product Quality Assurance (PPQA) : 4 questions

The number of questions was determined beforehand, since the number of questions reflects the importance of each process area. Extended Maturity Questionnaire was taken as the tool for data collection as it is simple, easy to handle and is the appropriate tool to get the partially achieved status. We designed a 5 scale EMQ with 5 answers,

- Achieved
- Partially Achieved
- Does Not Apply
- No
- Don't Know.

EMQ's were given to a minimum of five persons in each organization; sufficient time was given to finish the questionnaire. Then the filled in and answered questionnaire form were collected back. Questionnaires were given to mainly developers and team leaders and project manager / project leader. In each organization, 3 software developers, their team leader and finally their project leader / manager were questioned as a part of the assessment. Based on the individual answers about each process area, marks were allotted and a final score was calculated for each process area from the five questionnaires. Similarly, all process area scores were calculated and finally they were summed up for a final score of the corresponding organization. A sample set of questionnaire for process assessment in Project Management is presented below.

Intermediate Score:
The intermediate scores were processed using fuzzy logic. The level of organisation in each process area is manipulated using fuzzy logic. Organisations which are good in some process areas, show average performance in few process areas and poor performance in some. Two organizations stand in same rank in some process areas. In such a scenario it is difficult to find the best organization. This kind of ambiguity was eliminated applying fuzzy logic.

Capability Level of each organization is shown in the figure 2a – 2e, these figures depicts the final result of each organization after the implementation of framework. Intermediate score is shown in figure 3.

Table 3: Intermediate score of organizations

PROCESS AREA	ORGANIZATION				
	A	B	C	D	E
PP	5	7	4	6	6
PMC	4	7	5	5	6
RSKM	2	6	3	6	6
REQM	4	8	6	6	6
RD	3	6	5	6	7
TS	3	8	4	6	6
VER	2	8	4	5	6
VAL	3	8	6	6	6
PI	2	6	5	5	7
OT	4	8	4	6	7
OPD	4	6	3	5	4
OPF	6	8	5	6	7
PPQA	5	7	5	7	7
Grand Total	**47**	**93**	**59**	**75**	**81**

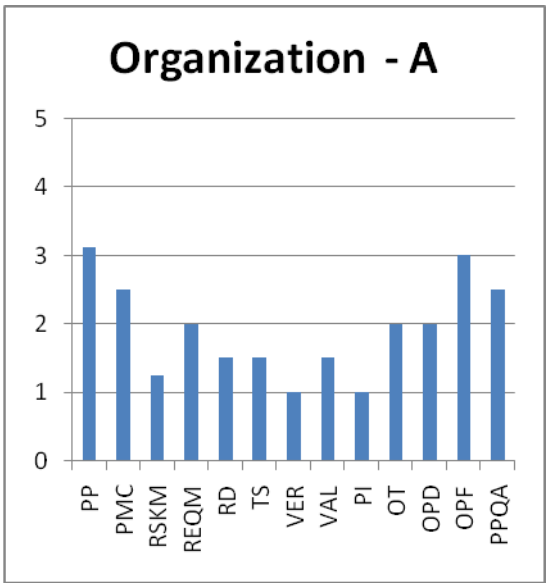
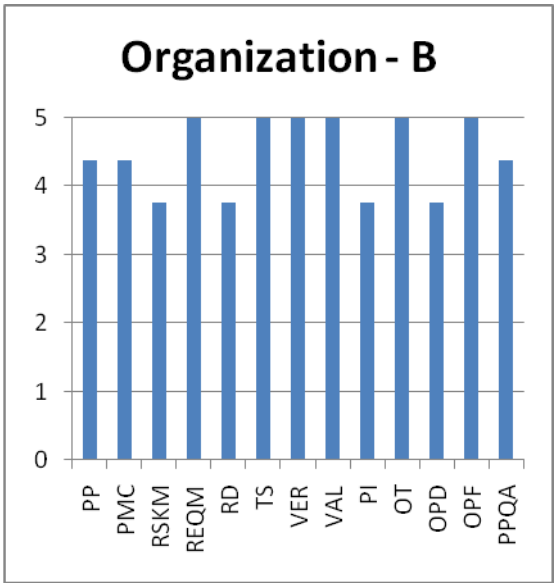


Figure 2a.



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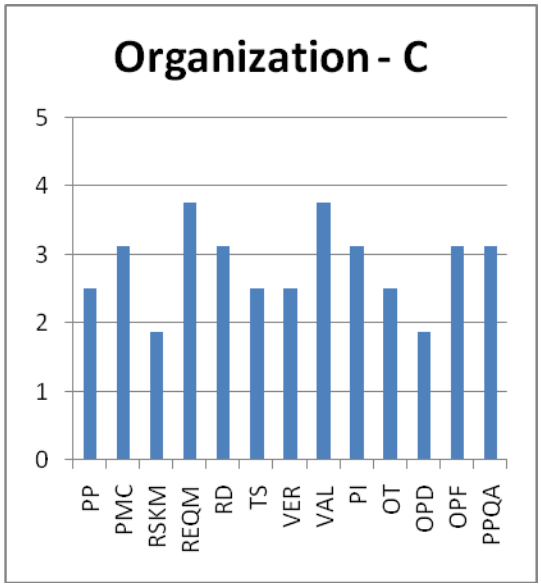

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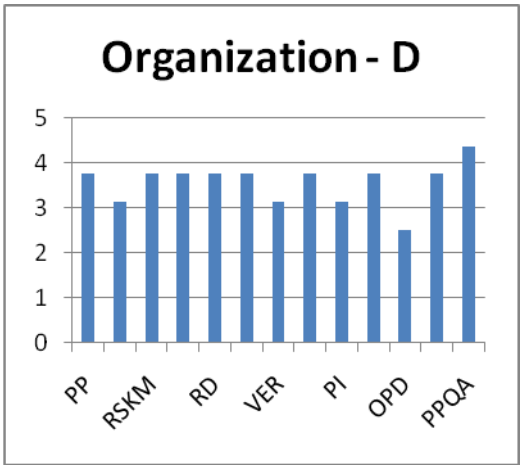

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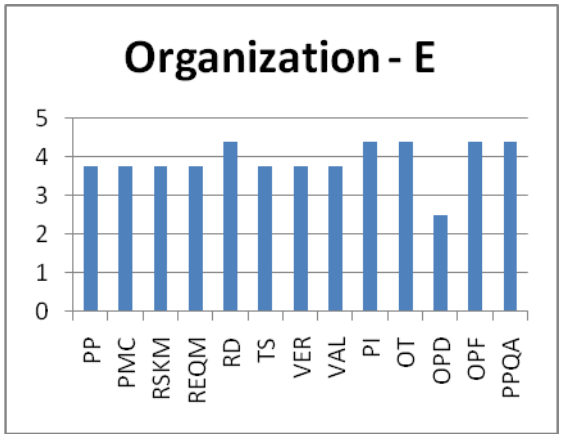

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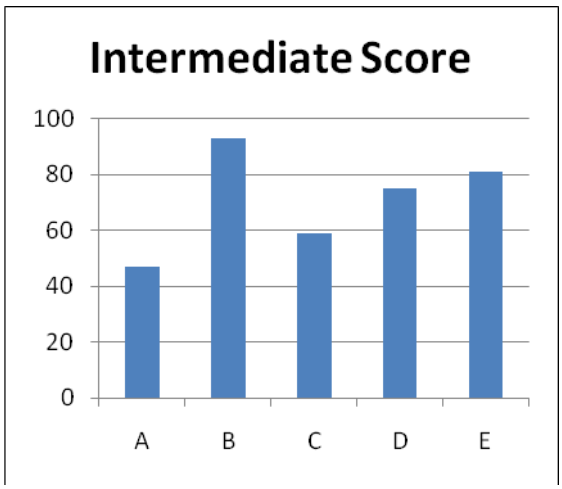

Figure 3 : Intermediate Score

3.1.1 Fuzzy Logic

The term "fuzzy logic" introduces by Zadeh is used to handle situations where precise answers cannot be determined. Fuzzy logic is a form of algebra which is based on the two values true and false, for the purpose of decision making with imprecise data. Fuzzy logic uses the whole interval between 0 (false) and 1(True) to describe human reasoning. There is an intimate connection between Fuzziness and Complexity. As the complexity of a task (problem), or of a system for performing that task, exceeds a certain threshold, the system must necessarily become fuzzy in nature. As a result, fuzzy logic is being applied in various real world problems. Zadeh explained that the purpose of fuzzy logic is to provide a variety of concepts and techniques for representing and inferring from knowledge that is imprecise, uncertain or lacking reliability. The fuzzy logic inference system involves various steps to process the input and to produce output. These steps are discussed below:

Step 0 – Linguistic Variable and Membership Mapping:
Linguistic variables take on linguistic values in fuzzy logic in the same way that numeric variables have numeric values. Linguistic variables are words commonly known as linguistic; for example, in order to describe height, we can use three linguistic variables such as short, average and tall. Each linguistic term is associated with a fuzzy set, each of which has a defined membership function (MF). A membership function is a curve that defines the way in which each point in the input space is mapped to a membership value between 0 and 1. For Example, one can consider a universal range of 40 inches to 80 inches for the height of a person as well as the three linguistic variables such as short, average and tall for mapping.

Step – 1 Fuzzification:
Fuzzification is the step at which we consider applied inputs and determine the degree to which they belong in each of the appropriate fuzzy sets via membership functions. For example if we have an input value of 50 as height, then accordingly the results will be 0.8 short, 0.1 medium and 0 tall.

Step – 2 Apply Rules:
"If – then" rules specify a relationship between the input and output for fuzzy sets. The "if" part of the rule, "x is A" is called the antecedent, while the "then" part of the rule, "y is B" is called the consequent or conclusion. If a rule has more than one part, for example," If x is A and y is B then z is C", the fuzzy logical operators are applied to evaluate the composite firing strength of the rule. The purpose applying rules is to find out the degree to which the antecedent is satisfied for each rule.

Step – 3 Apply Implication Method:
The implication is defined as the shaping of the output membership functions on the basis of the rule's firing strength. The input for the implication process is a single number given by the antecedent and the output is a fuzzy set. Two commonly used methods of implication are the minimum and the product.

Step – 4 Aggregate All Outputs:
Aggregation is a process where the outputs of each rule are unified. Aggregation occurs only once for each output variable. The input for the aggregation process is truncated output fuzzy sets returned by the implication process for each rule. The output of the aggregation process is the combined output fuzzy set.

Step – 5 Defuzzify:
The input for the defuzzification is a fuzzy set and the output of the process is a value obtained by using a defuzzification method such as height, centroid or maximum[8].

3.12 Processing of Intermediate Score using Fuzzy Logic:

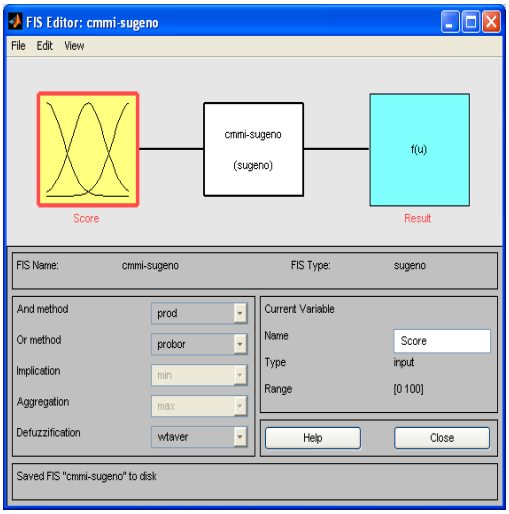

Figure 4 : Sugeno Model.

Fuzzy logic provides a variety of concepts and techniques for representing and inferring from knowledge that is imprecise, uncertain or lacking reliability. It is used to handle situations where precise answers cannot be determined. It is a form of algebra, which deals with a range of values from "true" to "false" for the purpose of decision-making with imprecise data[8].

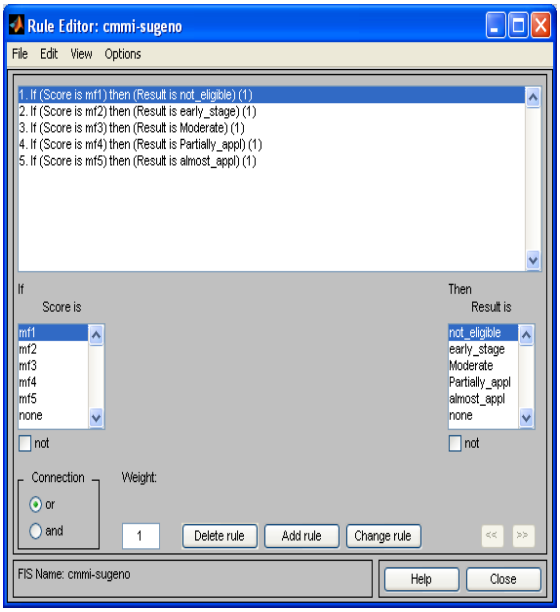

Figure 5: Rules

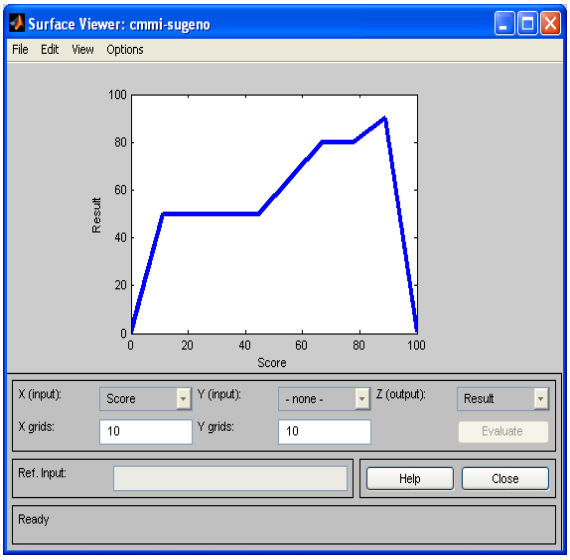

Figure 6 : Surface View

Two most commonly used fuzzy inference methods are Mamdani and Sugeno, The intermediate score was collected and given to a single variable fuzzy logic sugeno model described in figure 4. The output is calculated by applying sugeno min inference operator. Once all the rules have been applied as shown in figure 5, wtaver is used to evaluate the final output. Surface view is shown in figure 6.

4. Case Study and Discussion of the results obtained

The assessments were conducted in order to validate the framework. The questionnaire were distributed to 5 Indian software organizations. For experimental purpose, the organizations are coded 'A', 'B','C','D' and 'E'. We asked the respondents to refer to the major sources of data in organization such as plans, models and relevant documents before responding to the questionnaire, in order to reduce the tendency to overestimate or underestimate their Organization, while filling the questionnaire. Since we have given the same set of questionnaire to different persons in an organization, we used an average of all the responses received from the particular organization.

The results were given in table 3 & 4. They show organization B has higher scores and has the higher success rate to attain CMMI level. Organization E has score nearer to organization B and it is capable of attaining the CMMI maturity level early than other 3 organization. Further assessment of organization D by the authors indicated that the organization can attain CMMI level with a little more effort.

Table 4: Analysis of responses from the organization.

Organization	Project Management	Engineering	Process Management	Support
A	11 V. L.	17 V. L.	14 Low	5 Low
B	20 V. H.	44 V. H.	22 V. H.	7 High
C	12 V. L	30 Low	12 V. L.	5 Low
D	17 High	34 High	17 High	7 High
E	18 High	38 High	18 High	7 High

V. H. – Very High
V. L. – Very Low

Further assessments of organization C and organization A showed that they were not concentrating in process improvement activities. They admit that they does not follow any disciplined way of following a model like CMMI. These organizations were influenced by the knowledge and capability of senior most personalities in the organization.

5. Conclusion

A framework was developed to make quick and easy assessment of their level of achieving process assessment. The method is especially meant to be used by smaller organizations being newly introduced to CMMI, for quick self assessment of whether process area maturity is attained or not. It helps to know the SSMEs, their level of maturity in each process area. This method was applied to five Small software organizations in India to assess their process activities. The results show that the framework can be used for the purposes stated. A threshold can be placed at a score of about 80% to indicate success. A higher score indicates that they are above the average level in each process area and their maturity level is high when compared to other organizations. This framework can further be developed as an online tool so that it can support organizations in continuous assessment. It helps to assess their maturity level periodically. It also helps to improve organizations to attain CMMI standards.

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Authors Profile

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