



# Measuring the maturity of Indian small and medium enterprises for unofficial readiness for capability maturity model integration-based software process improvement

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## Abstract

Establishing the maturity levels of - Small and Medium Enterprises (SMEs) without Capability Maturity Model Integration (CMMI) certification has always been regarded as an extremely challenging task. Software process improvement (SPI) has targeted to monitor and improve software processes, thereby improving the software business. Although there is scientific interest in SPI, little attention has been specifically given to the exploration of maturity levels for non-CMMI SMEs. The goal is to explore the effect of time on process maturity and maturity levels achieved informally or unofficially by SMEs that are not otherwise CMMI certified. To find out the maturity levels achieved informally, a CMMI-DEV v1.3 based survey questionnaire is administered to Indian software SMEs. Time of establishment of SMEs and follow-up of CMMI-based processes and practices unofficially are used as two important parameters to decide upon process maturity and achievement of specific CMMI level informally. This paper has been successful in ascertaining the effect of time of establishment of SMEs and follow-up of CMMI-based processes on process maturity using proposed RuleML that advocates adoption of more than 70% of CMMI-DEV v1.3 process area-specific practices for an SME to be unofficially ready for CMMI-based SPI initiatives. The findings manifest multidimensional aspects of unofficial readiness of SMEs for CMMI-based SPI that can be used by relevant authorities to select SMEs for funding for SPI initiatives. Finally, the proposed work has been validated statistically using *t*-test for CMMI Level II and Level III.

## KEYWORDS

capability maturity model integration, CMMI-DEV v1.3 process areas and specific practices, small and medium enterprises, software process improvement

## 1 | INTRODUCTION

Various software process improvement (SPI) models exist in software industry, namely, capability maturity model (CMM), capability maturity model integration (CMMI), people software process (PSP), software process improvement and capability determination (SPICE), and BOOTSTRAP.<sup>1</sup> Berente and Lee<sup>1</sup> explored and suggested that these models have been providing continuous improvement and an edge to sustainable software development. CMMI Model has been seen as a generic model suitable for various industries. Veldman and Klingenberg<sup>2</sup> have established

CMMI as the excellent process framework adopted by software enterprises (SEs) containing the best practices that can be referred by other companies. Beecham et al.<sup>3</sup> explained software engineering as a challenging profession and therefore SPI. Baddoo et al.<sup>4</sup> discussed adherence to good practices results in software project success in high maturity organizations. Zephir et al.<sup>5</sup> working on the European project, tried to evaluate the maturity of the enterprise by applying novel practices characterized as a change with respect to structure or technology. Niazi et al.<sup>6</sup> have explored that even highly resourceful organizations are not able to achieve desired maturity levels and results. Al-Tarawneh et al.<sup>7</sup> have discussed different stages of a framework for improving the process of software development in small SEs. Integration of SPI model as CMMI and method of development as extreme programming (XP) has been discussed as a novel approach for SPI. Team<sup>8</sup> has emphasized that present century has to be characterized by a high-technology environment where even SMEs want to roll-out highly qualified products and services in a short period of time. Hosalkar and Bowonder<sup>9</sup> have identified that usage of software quality management (SQM) enabled SEs to reduce development time, speedy delivery of products with higher quality, and satisfaction of market needs. Lester et al.<sup>10</sup> have discussed appraisals of 10 small and medium enterprises (SMEs) practicing software development. It has been noticed by the researchers that software organizations started following a greater number of practices of CMMI as they have grown in size. Berente and Lee<sup>1</sup> have emphasized on technological innovation management to theorize and organize SPI efforts in organizations. The authors have formulated a set of four categories of propositions. The example of four categories are direct, resource capacity, knowledge, and management vision.<sup>11</sup> Wubben et al.<sup>12</sup> have found innovation important for the growth of any organization. Singh and Aggarwal<sup>13</sup> identified numerous facilitating factors that could provide a fertile ground for software process reengineering in achieving CMMI levels.

## 1.1 | Motivation

The main objective of the present work is to identify the trends of acceptance and adoption of well-known SPI standard, that is, CMMI-DEV v1.3 informally by SMEs. Time-specific investigation is carried out for the purpose as the attainment of CMMI levels consumed huge time that is indicated and reported by Software Engineering Institute.<sup>14</sup> The following research questions (RQs) have been framed to reach a conclusion.

RQ I: What is the difference between the maturity levels of Indian non-CMMI SMEs established for less than 5 years and non-CMMI SMEs established for more than 5 years?

RQ II: Which CMMI maturity level can be given to Indian SMEs unofficially on the basis of informal adoption of CMMI-DEV v1.3 process area-specific practices?

This paper is motivated by a study carried out by Iqbal et al.<sup>15</sup> who proposed to explore the unofficial readiness of software organizations towards CMMI. There are number of SMEs that are delivering great products developed using qualified processes. These SMEs are not certified by any external or international organizations like CMM or CMMI. The authors evaluated the unofficial readiness of such SMEs towards CMMI basing the study on the percentage of adoption of CMMI practices. This paper replicated the study carried out by Iqbal et al.<sup>15</sup> We followed the methodology adopted by Iqbal et al.<sup>15</sup> with a little variation in selecting ratings for percentages of follow-up of CMMI practices, for evaluating unofficial readiness of Indian SMEs towards CMMI. Indian SMEs are performing well and are also contributing to gross domestic product (GDP). This is the first paper that evaluates the CMMI maturity of Indian non-CMMI SMEs. The methodology is applied taking noncertified Indian software SMEs into consideration to find their maturity index according to CMMI practices on the basis of their time of establishment.

## 1.2 | Article structure

The rest of the paper is organized in six different sections. Section 2 discusses the significance, awareness, and evolution of CMMI as a staged and continuous model. Section 3 guides through the research methodology followed for the research work. Section 4 firstly elaborates upon the methodology applied to answer RQ I and RQ II. It rigorously compares and analyses non-CMMI SMEs that are established within 5 years and non-CMMI SMEs that are established for more than 5 years. Section 5 outlines the results, and Section 6 concludes the research work.

## 2 | CMMI AND SPI AWARENESS IN SMES

SMEs realize the importance of SPI equally as most of the big organizations do, but it is not possible for SMEs to achieve excellence in their software processes easily. Integration of process and quality improvement has already gained popularity across the globe.<sup>16,17</sup> Different researchers have been working on performance and process maturity of the software SMEs worldwide. O'Connor and Coleman<sup>18</sup> have highlighted the underlying critical issues in the adoption of CMMI as SPI model in Irish SMEs. Yang et al.<sup>19</sup> have come with a study that showed the necessity to evaluate software industry in China. Kim and Park<sup>20</sup> have explored the impact of open innovation strategy on Korean SMEs. Mishra and Mishra<sup>21</sup> have studied and analyzed the status of Indian software SMEs. Ali and Ibrahim<sup>22</sup> have developed an application tool to implement SPI in Malaysia's

SME. Dyba<sup>23</sup> emphasized that SMEs should concentrate on human resource engagement in SPI activities in their organization. Allen et al.<sup>24</sup> have discussed PRISM as a dedicated guidance model for implementation of SPI in SMEs. The researchers have indicated the availability of an online tool for administrating the SPI activities in SMEs. Garcia et al.<sup>25</sup> have carried out a methodical survey of related text or literature available for SPI. Pino et al.<sup>26</sup> have focused on execution of SPI tasks in SMEs. SPI is really crucial for improving the status and maturity level of SMEs. Unavailability and sometimes limited SPI resources like huge SPI initiative cost for its implementation and constrained project completion deadlines have often posed hindrance in SPI adoption and assimilation. Mishra and Mishra<sup>21</sup> have suggested and contrasted methodologies for the underlying problems encountered by SMEs in the SPI endeavors. Alexandre et al.<sup>27</sup> have recommended a method to accelerate SPI endeavors in SMEs. The researchers have presented the solutions of SPI implementation with available budget constraints. Khokhar et al.<sup>28</sup> have reviewed and identified a number of critical issues and attributes of SPI in SMEs. Sulayman and Mendes<sup>29</sup> have carried out a survey on SPI initiatives and specific tools and methods for SMEs engaged in web development. SMEs associated with web development encountered same issues such as constrained allocation of budget and timelines. These web-based organizations often failed to plan in terms of long-term SPI goals. Sulayman et al.<sup>30</sup> have proposed a unique framework in pursuit to identify crucial parameters in such web SMEs. Garcia and Pacheco<sup>31</sup> have tried to assist SMEs in their initial SPI initiatives. The authors have implemented SPI automation, but certain problems surfaced, and SMEs were not able to access the provided automated system. Pino et al.<sup>32</sup> have come up with a solution by proposing a technique to handle the underlying limitations. Al-Tarawneh et al.<sup>7</sup> have suggested incorporation of famous SPI model, that is, CMMI in one of the stages of the proposed framework. The other stage of the framework included one of the agile methodologies, that is, extreme programming for development. The authors have highlighted that the two staged frameworks would definitely improve the software development process.

## 2.1 | Evolution of staging and maturity levels

An adaptation of maturity level (ML) index has been used to measure continuous improvements and adoptions. It has been originally introduced by Bessant and Caffyn.<sup>33</sup> Existing research work<sup>33–37</sup> have refined the model further by index ranges from ML 0: randomness, that is, no activity to ML 5: learning organization (initiate to become an integral part of the organization). The MLs have been shown in Table 1.

With the passage of time, many authors have discussed step by step progression of maturity and related it with certain kind of innovation.<sup>37,5</sup> Garzás & Paulk,<sup>38–40</sup> have identified many general patterns and synthesized various stage models as following: (1) top management gets to know about an innovation; (2) a problem matching to the innovation is found; (3) cost of innovation and benefit of adopting the innovation are appraised; (4) process is influenced by many sources positively or negatively; (5) a decision, either adopt or reject the innovation, is made; (6) implementation of innovation is done; (7) examination of decision regarding the novel thing is done, and innovation is accepted or rejected; and (8) the innovation is adopted as a routine, and adopted innovation is infused in the organization. Moreover, the staged models had been developed mainly for technical innovations. A process of management innovation has been outlined by Birkinshaw et al.<sup>42</sup> but that framework dealt with the development of innovations new to the market rather than the adoption of innovations new to the organization.

## 2.2 | Maturity as a concept in CMMI

The choice of SPI model is based on a list of factors.<sup>43</sup> These factors include resource availability, cost, business or marketing process needs, internal knowledge, time frame, and business strategy.<sup>44</sup> Each of the models used, however, would give an organization some sort of framework through which it can establish the goals and objectives it needs to reach, within some specified period of time.<sup>45</sup> Most organizations normally implement a part of some process improvement first to assess its compatibility with the organization, before a full-fledged implementation of the SPI.<sup>46</sup> We have concentrated on CMM and CMMI as a base to evaluate the current scenario and trends with respect to maturity attained by SMEs.

**TABLE 1** Software process quality improvement maturity levels (MLs)

MLs	Description	Typical characteristics
0	Random	Activity with no formal efforts
1	Trying out	Occurrence attributed to particular difficulty inspired from training guidance and characterized as confined and short spanned
2	Formally structured	The structured effort, little training, lack integration with business strategy
3	Strategic	Efforts towards planned goals and measurement do not take into account such goals
4	Empowering	Strategic processes realized with integration of top-down focus with bottom-up actions
5	Learning organization	Sharing the knowledge gathered for adaptations

Source: Bessant and Caffyn<sup>33</sup> and Chapman and Hyland.<sup>34</sup>

### 2.2.1 | Capability maturity model

CMM is a framework that evaluates the contractor's ability to deliver a qualified product.<sup>14</sup> The objective of the model was to improve on software discipline in project cases that were multicontractor or multilayered.<sup>47</sup> The basis of the model is the capability of the organization or the project, with respect to five levels<sup>48</sup>. Each of these levels has a set of processes that are defined within them. These levels are referred to as maturity levels.<sup>6</sup> They are crucial for the prioritization of the steps involved within SPI.<sup>49, 50</sup> Additionally, they are important for the identification of the different improvements that can be implemented and increase benefits to the organization within short-term periods.<sup>51</sup> Also, the model aims at a process's constant improvement.<sup>52</sup> The management and organization should constantly strive to improve the software processes and continuously refine them. The evaluation of CMM's maturity levels with respect to process, result, and lacking are presented in Table 2.

### 2.2.2 | Capability maturity model integration

Team<sup>8,14</sup> has come up with a new integrated approach known as CMMI that further integrated and standardized CMM while eliminating its limitations. CMMI documents industry best practices categorized on separate areas of interests rather than separate functions. Organizations choose from any of the available models, depending on the business objectives, and each model covers all the functional areas. The main concern is to find the difference between CMM and CMMI that is discussed in the following section.

### 2.2.3 | Comparison of CMM and CMMI

Process maturity has been defined in five different levels for CMM and CMMI.<sup>28</sup> These levels are based on significant process areas (PAs) defined for a particular level. These PAs in CMMI have conquered the architectural flaws existent in CMM processes.

- Level I (Initial): Immaturity existing in organizations has been regarded as a major characteristic of the initial level, that is, software development processes are not well defined. Organizations at this level have been working in an ad hoc and reactive manner having undefined processes with no control over processes.
- Level II (Repeatable): Attainment of Level II of CMM can be realized just by repeating processes for similar type of projects. Level II of CMMI requires the implementation of requirement management through process planning, performing, measuring, and controlling processes. At CMMI Level II, process is repeatable on similar kind of projects, that is, there exists number of process models that are followed on similar kind of projects.
- Level III (Defined): Level III of CMM has emphasized on establishing a consistent process across the organization. Usage of defined and documented standard processes has been used to achieve such kind of consistency. Level III of CMMI can be seen as an enhancement of CMMI Level II. At CMMI Level III, the organization has a set and defined standard process model, organizational processes, procedures, tools, and methods.
- Level IV (Managed): CMM Level IV emphasizes on the attainment of charge over processes. This can be achieved using statistical tools and techniques for measuring the process quantitatively. Similarly, CMMI Level IV establishes control over processes while identifying subprocesses that can contribute towards efficient processes.
- Level V (Optimized): CMM Level V stresses the need to manage processes quantitatively. Whereas managing continuous process improvement quantitatively has been the central point of focus in CMMI Level V.

**TABLE 2** MLs of CMM framework evaluated with respect to process, result, and lacking<sup>28</sup>

Attributes	Level I ad hoc	Level II repeatable	Level III defined	Level IV managed	Level V optimized
Process	Undefined ad hoc	Tracks documents, cost, schedule, and functionality	Documented, standardized, and tailorable	Detailed measurement; control	Continual process improvement through quantitative feedback
Result	The outcome depends on individuals	Repeatable on similar projects	Consistency	Process and products with quantified quality predictability	Qualified product
Lacking	Any reasonable process	Complete process	Predictable outcomes	The mechanism for process improvement	N.A.

CMM can be seen as a certification instrument but CMMI cannot be. The degree of adoption of CMMI model actually has been taken as a deciding factor for the CMMI Rating (I–V).

## 2.2.4 | Our contributions

The research work attempts to evaluate the maturity levels of Indian SMEs informally, that is, the study has taken a sample of SMEs that are not CMMI certified but otherwise follow CMMI practices. In particular, it presents the results of an evaluation to rate these SMEs on the CMMI scale. This paper has been extending our previous research work<sup>13</sup> and aims to point out the facilitating factors in SPI that can really boost the quality of software processes to provide a competitive edge to the software SMEs. It also identifies the top 15 factors encompassing project workflow, team culture, organization culture, SPI culture, organization culture, process guidance, high-level planning, product delivery, alignment and integration, change management, and process improvisation.

After identifying the critical success factors for SPI programs in SMEs in our previous research work,<sup>13</sup> the present research focuses on the evaluation of unofficial readiness of non-CMMI SMEs. The present research work is motivated by<sup>15</sup> and has taken their work as base. It concentrates on the unofficial readiness for CMMI-based SPI among SMEs, which can be used to define criteria for the selection of SMEs that would be included in SPI initiatives funded by relevant authorities. It differs from existing work for the following reasons:

- 1 The time of establishment of SMEs was taken as an important parameter for ascertaining the CMMI maturity.
- 2 The present research work is important and different from others as there is no such existing study for Indian SME.

## 3 | RESEARCH METHODOLOGY

The research methodology adopted for the current study is explained below.

### 3.1 | Data and sample

Descriptive research design and random stratified sampling elaborated by Rea and Parker<sup>36</sup> and Kish<sup>53</sup> have been used for the present research. Random stratified sampling technique has been used with a sample size of 120 respondents. The sample size seems appropriate as it has been calculated 116 in Equation (1), which is discussed by Rea and Parker<sup>36</sup> and Kish<sup>53</sup>

Size of the sample (SS) can be calculated as follows:

$$SS = Z^2 * p * q * N / (e^2 * (N - 1) + Z^2 * p * q), \quad (1)$$

where

Z is level of confidence

p is response distribution

q is (1-p)

e is margin of error

N is population

With the population size  $N = 2,000$ ,

Level of confidence = 95%

Response distribution = 50%

Margin of error = 8%,

SS = 116 as per Equation (1)

The sampling unit is India. The response of the respondents has been measured on a 5-point likert scale. In all, 300 questionnaires were distributed online through emails to senior, middle, and lower level management of software companies. The questionnaires were also given to be filled by senior, middle, and lower level management of software companies at nearby places like Chandigarh, Noida, Gurgaon, and Delhi using professional references. As many as 163 responses were received, 120 of them found to be complete in all aspects that formed the basis of this

study for further analysis. Out of 120, 60 responses were selected on the basis of the time of establishment of the SME in which 30 were established for more than 5 years, and 30 SMEs were established for less than 5 years. The response rate is good for evaluation CMMI maturity levels for non-SMEs. More elaboration is given in Section 4.2.

The data were collected from the managers working at three different hierarchical levels of Indian SMEs under study. The questionnaire-cum-interview method was used to collect the primary data from the selected respondents. The questionnaire has three sections. The first two sections address the stage of development of SPI in SMEs and also concentrate on finding the effect of time on SPI and organizational capabilities. The third section of the questionnaire has been based on CMMI-DEV v1.3 PAs and specific practices (SPs) exhibited in Table 7. The questionnaire has been designed based on the CMMI-DEV V1.3 and detailed discussion with many academicians, professionals, and industry experts. The participants have been both identified at random and selected based on professional contacts of the researchers. The pilot testing was done on 28 respondents in totality at three levels of management such as senior, middle, and lower level in four companies as mentioned in Table 4. To ensure the quality of the instrument, the questionnaire was tested for reliability, content validity, and sensitivity. The questionnaire chosen for the study was found to be reliable as Cronbach's  $\alpha$  given by Cronbach<sup>54</sup> and discussed by Nunnally<sup>55</sup> came to be .956, indicating the goodness of the scale. Content validity of the questionnaire was tested through discussions for comprehensiveness, depth, and relevance to the selected organizations and topic of the study. The questionnaire has been found to be comprehensive, appropriate, and relevant to the study as number of changes done based upon the feedback given by experts on academia and industry.

## 3.2 | For the organizations

Universe of study: Small and medium software development organizations of India.

The present study is focused on SMEs in India. In the context of Indian software industry, the organization for Economic Cooperation and Development (OECD) categorizes organizations on the basis of their number of employees, which has been shown in Table 3.

## 3.3 | Sample selection

This section discusses the sample selection for the research work.

### 3.3.1 | For the respondents

- 1 Universe of the study: Managers working at three different levels in the hierarchy existing in the selected organizations.
- 2 Sample Selection: The respondents have been selected from the organizations under study through the random stratified sampling technique. They have been identified from the various levels of management such as senior, middle, and lower levels. The respondents present the different positions and role names with respect to their organization. These have been categorized as shown in Table 4.

**TABLE 3** Size of software organizations on the basis of head counts

Category	No. of employees
Very small	Up to 19
Small	20 to 99
Medium	100 to 499
Large	500 and above

**TABLE 4** Managers working at three different hierarchical levels

Levels of management	Positions or roles
I. Senior level	CEO, chairman, director, president, and vice president
II. Middle level	Project manager, project lead, team lead, senior manager, senior software engineer, senior quality assurance manager, and quality team lead
III. Lower level	Software engineer, software developer, software testers, system and business analyst, and trainees

## 4 | TREND EVALUATION FOR MATURITY LEVELS IN NON-CMMI SMES

This section gives appropriate ground to select the time of establishment of SMEs as a significant parameter to study process maturity. It also underlines the methodology and criterion to decide upon maturity levels achieved by non-CMMI SMEs informally.

### 4.1 | Effect of time on process maturity in SMEs

This section explores the third research question under study. SEI<sup>14</sup> reported that the attainment of CMMI level consumes huge time. It is estimated that achieving CMMI Level V (SCAMPI) takes 54.5 months approximately, and time is the cost to be paid for process maturity. Therefore, the present study has selected time being a crucial parameter to be taken into account while making any concrete decision of maturity levels for non-CMMI SMEs. It has been found that there is a significant effect of time on SPI factors and organizational capabilities that are also depicted in Figure 1 and Finding I discussed in Section 4.1.1.

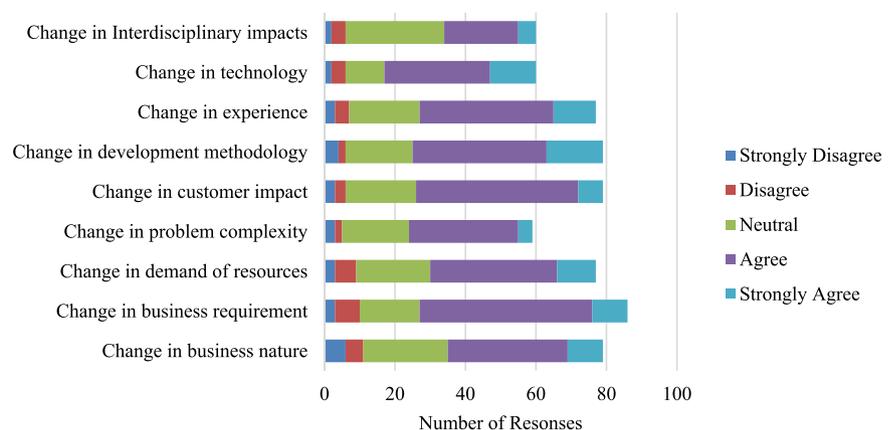
#### 4.1.1 | Effect of time on SPI factors and organizational capabilities

Time being the important parameter in deciding the CMMI maturity rating, the factors in Table 5 was explored. The response set on Likert stage has been tabulated in Table 5.

Changes occur with the passage of time in any software process. Numerous factors are depicted in Figure 1 that changes with the time. For each factor, respondents reply (in percentage) for aggregate of agree and strongly agree replies is as follows: changes in business nature (56%) and changes in business requirement (68%), change in demand of resources (61%), change in complexity (59%), change in customer impact (67%), change in development methodology (68%), change in experience (63%), and change in technology (72%).

Finding I: Most significant effects of time on SPI factors and organizational capabilities are change in technology, change in business requirement, change in development methodology, and change in customer impact are the main factors that prominently changes with time. Change in interdisciplinary impacts is the one factors that is not much affected by the time.

**FIGURE 1** Response regarding software process improvement (SPI) factors and organizational capabilities (SPI factors that changes with time and their responses) [Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]



**TABLE 5** Response set for software process improvement (SPI) factors and organizational capabilities

Factors	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Change in business nature	6	5	24	34	10
Change in business requirement	3	7	17	49	10
Change in demand of resources	3	6	21	36	11
Change in problem complexity	3	2	19	31	4
Change in customer impact	3	3	20	46	7
Change in development methodology	4	2	19	38	16
Change in experience	3	4	20	38	12
Change in technology	2	4	11	30	13
Change in interdisciplinary impacts	2	4	28	21	5

Now, we tend to find the effect of time on process maturity and maturity levels for non-CMMI SMEs.

## 4.2 | Methodology elaborated

Out of 120 SMEs studied for organizational culture in Section 3, 60 SMEs have been found appropriate to be studied and analyzed on the basis of the time of establishment. As the effect of time on process maturity is of main concern for taking any decision on maturity levels, we have divided SMEs into two categories: SMEs established for more than 5 years and SMEs established for less than 5 years. SMEs were selected on the basis of their time of establishment. Among 60 SMEs, 30 SMEs were scrutinized for being established for greater than 5 years, and 30 SMEs were scrutinized for being established for less than 5 years.

## 4.3 | Criterion to decide on maturity level

Wilkie et al.<sup>56</sup> studied and categorized PA-SPs set of CMMI Level II having high (greater than 70%), medium (between 70% and 40%), and low (lesser than 40%). In a similar study, Iqbal et al.<sup>15</sup> have used corresponding percentages with a little difference (75% as a replacement for 70% and 50% as a replacement for 40%) to reflect the number of SPs in CMMI Level N (I-V) process areas. In the present study, instead of three divisions on the percentage of PA-SPs adopted and practiced by SMEs completing more than 5 years and SMEs not completing 5 years, we have divided it into four parts: low (<50%), medium (50%–70%), high (71%–90%), and very high (>90%). Iqbal et al.<sup>15</sup> have taken more than 50% adoption of SPs for semipotential organizations and more than 70% for potential organizations for CMMI rating. In the present study, we are concentrating on the evaluation of the candidature of non-CMMI SMEs for achieved closer to CMMI maturity levels. Table 6 presents the comparison of Iqbal et al.<sup>15</sup> work with our proposed approach for taking up variations in the adoption percentage brackets of CMMI practices. The following criteria or rule has been established in order to confine a non-CMMI SME for achieving specific CMMI maturity level if it has been found practicing more than 70% of SPs for that particular maturity level.

Here, we have been emphasizing on SPs of respective PAs in particular MLs. SPs are a set of activities defined in CMMI v1.3 that are essential for achieving specific goals (SGs) of PAs. Team<sup>8</sup> in their technical report, has described the 22 PAs and 167 SPs. Based upon the work of Team<sup>8</sup> we have developed the measuring instrument having major PAs with respective SPs in that particular PA. In the following Table 7, we have incorporated count (#) of SPs, in particular PA, and further associated the PA and SPs with the ML Rating.

### 4.3.1 | Possible number of specific practices in particular CMMI level

Table 8 shows the possible number of specific practices in particular for CMMI Level II according to the approach in Table 6 for RuleML.

Table 9 shows the possible number of specific practices in particular for CMMI Level III according to the approach in Table 6 for RuleML.

### 4.3.2 | RuleML

To decide on MLs for non-CMMI-certified SMEs, RuleML has been established to assign a particular maturity level to given SMEs. RuleML is based on the strategies used by Wilkie et al.<sup>56</sup> and Iqbal et al.<sup>15</sup> with little modifications in percentages of specific practices followed in order to decide the CMMI level of a software organization that is not CMMI certified. The underlying variation in adoption brackets for<sup>15</sup> and our proposed approach is discussed in Table 6 in Section 4.3. RuleML follows Tables 8 and 9 for possible number of specific practices in CMMI Level III under relevant percentages. Algorithm for RuleML is further discussed in the following section:

**TABLE 6** Comparison of the adoption percentage brackets for CMMI PA-SPs set

Research work	Low	Medium	High	Very high	Comparison made
Iqbal et al. <sup>15</sup>	<50%	50%–70%	>70%	N.A.	Between small- and medium-sized enterprises
		Semipotential	Potential		
Our proposed approach (Rule ML)	<50%	50%–70%	71%–90%	>90%	Between SMEs (Estb. <5 years) and SMEs (Estb. >5 years)

Abbreviations: CMMI, capability maturity model integration; Estb., established; N.A., not applicable; PA, process area; SMEs, small and medium enterprises; SPs, specific practices.

**TABLE 7** Measuring instrument containing PAs with count of SPs and associated ML for CMMI-DEV v1.3

S. no.	PAs	Acronym used for PAs	SPs	ML	S. no.	PAs	Acronym used for PAs	SPs	ML
1	Requirements management	REQM	5	2	12	Organizational training	OT	7	3
2	Project planning	PP	14	2	13	Product integration	PI	9	3
3	Project monitoring and control	PMC	10	2	14	Requirements development	RD	10	3
4	Process and product quality assurance	PPQA	4	2	15	Risk management	RSKM	7	3
5	Configuration management	CM	7	2	16	Technical solution	TS	6	3
6	Measurement and analysis	MA	8	2	17	Validation	VAL	5	3
7	Supplier agreement management	SAM	6	2	18	Verification	VER	8	3
8	Decision analysis and resolution	DAR	6	3	19	Organizational process performance	OPP	5	4
9	Integrated project management	IPM	7	3	20	Quantitative project management	QPM	7	4
10	Organizational process definition	OPD	7	3	21	Organizational performance management	OPM	10	5
11	Organizational process focus	OPF	9	3	22	Causal analysis and resolution	CAR	5	5

<sup>a</sup>Source: <http://www.sei.cmu.edu/library/assets/whitepapers/CMMI%20DEV%20v1%203%20-%20TR%2011-2010%20Dutch.pdf>, retrieved on July 23, 2016.

Abbreviations: CMMI, Capability Maturity Model Integration; ML, maturity level; PAs, process areas; SPs, specific practices.

**TABLE 8** Possible number of specific practices in CMMI Level II under relevant percentages

Process areas	No. of specific practices in the various process areas of CMMI Level II	<50%	50%–70%	71%–90%	>90%
PPQA	4	0,1	2	3	4
REQM	5	0,1,2	3	4	5
SAM	6	0,1,2,3	4	5	6
CM	7	0,1,2,3	4	5,6	7
MA	8	0,1,2,3	4,5	6,7	8
PMC	10	0,1,2,3,4	5,6,7	8,9	10
PP	14	0,1,2,3,4,5,6	7,8,9	10,11,12	13,14

Abbreviations: CM, configuration management; CMMI, capability maturity model integration; MA, measurement and analysis; PMC, project monitoring and control; PP, project planning; PPQA, process and product quality assurance; REQM, requirements management; SAM, supplier agreement management.

**TABLE 9** Possible number of specific practices in CMMI Level III under relevant percentages

	No. of specific practices in the various process areas of CMMI Level III	<50%	50%–70%	71%–90%	>90%
DAR	6	0,1,2,3	4	5	6
IPM	7	0,1,2,3	4	5,6	7
OPD	7	0,1,2,3	4	5,6	7
OPF	9	0,1,2,3,4	5,6	7,8	9
OT	7	0,1,2,3	4	5,6	7
PI	9	0,1,2,3,4	5,6	7,8	9
RD	10	0,1,2,3,4	5,6,7	8,9	10
RSKM	7	0,1,2,3	4	5,6	7
TS	6	0,1,2,3	4	5	6
VAL	5	0,1,2	3	4	5
VER	8	0,1,2,3	4,5	6,7	8

Abbreviations: CMMI, capability maturity model integration; DAR, decision analysis and resolution; IPM, integrated project management; OPD, organizational process definition; OPF, organizational process focus; OT, organizational training; PI, product integration; RD, requirements development; RSKM, risk management; TS, technical solution; VAL, validation; VER, verification.

**ALGORITHM 1****RuleML**

```

DEFINE Adoption Bracket HIGH (71%-90%)
DEFINE Adoption Bracket VERY HIGH (> 90%)

INPUT: PA and SP followed by Non-CMMI organizations, Table 8 and Table 9
OUTPUT: CMMI level
BEGIN
  FOR (Non-CMMI SMEs)
    FOR (Particular PA and SP set at CMMI Level N)
      IF (Acceptance and Adoption percentage in the range HIGH OR VERY HIGH>70%)
        THEN
          Assign SME to prospective CMMI Level N
        ELSE
          Assign SME to Still Struggling List for CMMI Level N
        ENDIF
      END FOR
    END FOR
  END FOR
END

```

According to the RuleML, the organizations that agreed to follow CMMI Level II practices in the bracket 71%–90% will go in the prospective list of CMMI Level II companies. The organizations that are following the CMMI Level II practices less than 70% and are in the bracket 50%–70% will go to a still struggling list for CMMI Level II. Similarly, for CMMI Level III, the organizations need to follow more than 70% of specific practices of respective process areas of CMMI Level III. The actual percentage of organizations following specific practices in 71%–90% bracket and more than 90% are put in the prospective list. The total percentage is calculated by summing up these two brackets. The organizations that are not following specific practices up to 70% are put in a still struggling list CMMI Level III. We have made the comparison on the basis of CMMI PA and SP followed between SMEs established for less than 5 years and SMEs established for more than 5 years in Section 4.4.

#### 4.4 | CMMI Level II PAs and SPs

Table 10 depicting the number of responses received for CMMI Level II-based survey questionnaire. We have segregated the response according to the acceptance and adoption percentage as low (<50%), medium (50%–70%), high (71%–90%), and very high (>90%) for SPs of CMMI Level II processes and specific practices by noncertified SMEs.

We have formulated a RuleML described in Section 4.3.2 for deciding the CMMI maturity level of a particular SME. According to the rule, number of processes and SPs should lie in the high and very high zone as perceived value to achieve particular level. SEI<sup>14</sup> reported that the attainment of CMMI level consumes huge time. It is estimated that achieving CMMI Level V (SCAMPI) takes 54.5 months (5 years approximately) approximately, and time is the cost to be paid for process maturity.

##### 1 SMEs (Established [Estb.] >5 years)

- We have found while concentrating on the second last field, that is, Q, which is the sum of the two fields, J, and N, that 96% of SMEs pursued more than 70% of SPs followed for REQM processes in SMEs (Estb. >5 years). Similarly, for the processes PP, PMC, PPQA, CM, MA, and SAM, 93%, 94%, 83%, 95%, 83%, and 95% SMEs (Estb. >5 years), respectively, have been pursuing greater than 70% of SPs of CMMI Level II processes.
- These all are quite high figures and are appropriate to recognize that a good number of SMEs, which are established for more than 5 years, are following at least 70% of the processes in CMMI Level II.

**TABLE 10** CMMI Level II PA-SPs with adoption percentage in SMEs established for more than 5 years and SMEs established for less than 5 years

PA	<50%		50%–70%				71%–90%				>90%				AVG	AVG		
	SME >5 years		SME <5 years		SME >5 years		SME <5 years		SME >5 years		SME <5 years		SME >5 years		SME <5 years			
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	%	%		
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q = J + N	R = L + P
REQM	0	0	2	6	1	3	5	16	4	13	3	10	25	83	20	67	96	77
PP	0	0	1	3	2	6	8	26	5	16	5	16	23	77	16	53	93	69
PMC	1	3	1	3	1	3	7	23	4	13	4	13	24	80	18	60	93	73
PPQA	2	6	3	10	3	10	7	23	4	13	4	13	21	70	16	53	83	66
CM	0	0	2	6	2	6	4	13	6	20	5	16	22	73	19	63	93	79
MA	2	6	3	10	3	10	5	16	5	16	6	20	20	67	14	47	83	67
SAM	0	0	3	10	2	6	6	20	3	10	4	13	25	83	17	57	93	70
AVG %																	91	71

Abbreviations: CM, configuration management; CMMI, capability maturity model integration; MA, measurement and analysis; PA, process areas; PMC, project monitoring and control; PP, project planning; PPQA, process and product quality assurance; REQM, requirements management; SAM, supplier agreement management; SMEs, small and medium enterprises; SPs, specific practices.

- It has also been found while concentrating on N field that the number of SMEs (Estb. >5 years) following more than 90% of the SPs of CMMI Level II is high (i.e., 77%). The field N shows that the percentage greater than 70% of SMEs (Estb. >5 years) is following 90% of the SPs for CMMI Level II processes.
- It is very interesting to note the fact that 90% of the SPs are being followed in 70% to 83% of noncertified SMEs established for greater than 5 years as the values of N column lies between 70% and 83%.
- Focusing on P and L fields collectively, that is, 70% to 100% block (all together), greater SMEs (Estb. >5 years) lie in P field of >90% block, and lesser SMEs (Estb. >5 years) lie in L field of 71%–90% block.
- On an average, 91% of SMEs (Estb. >5 years) follow greater than 70% of SPs of CMMI Level II.

Summarizing the case of non-CMMI SMEs (Estb. >5 years) follow-up of 90%–100% SPs by 67% to 83% of SMEs that are established for more than 5 years

- Follow-up of 71%–100% SPs by 83% to 96% of SMEs that are established for more than 5 years.

## 2 SMEs (Estb. <5 years)

- The last field of Table 10, that is, R, gives the sum of L and P, which establishes that 77% of SMEs followed greater than 70% of SPs followed for REQM processes in SMEs (Estb. <5 years). Similarly, for the processes PP, PMC, PPQA, CM, MA, and SAM, 69%, 73%, 66%, 79%, 67%, and 70% SMEs (Estb. <5 years), respectively, have been following greater than 70% of SPs of CMMI Level II processes.
- As good number of SMEs, which are established for less than 5 years, are following at least 70% of the processes in CMMI Level II.
- It has also been found while focusing on the P field, that is, number of SMEs (Estb. <5 years) following greater than 90% of the SPs of CMMI Level II are not reaching high. REQM, PP, PMC, PPQA, CM, MA, and SAM in P field shows that the percentage of SMEs (Estb. <5 years) that are following 90% of the SPs for CMMI Level II processes is 67%, 53%, 60%, 53%, 63%, 47%, and 57%, respectively. Only 47% of SMEs (Estb. <5 years) are following 90% of SPs for measurement and analysis (MA). Ninety percent of SPs of PP and PPQA are followed by 53% of SMEs. PMC, CM, and REQM for 90% of SPs are being followed by 60%, 63%, and 67% of SMEs (Estb. <5 years).
- Though figures are not reaching high, it is very interesting to note the fact that 90% of the SPs are being followed in 53% to 67% of non-certified SMEs established for less than 5 years.
- Focusing on P and L fields collectively, that is, 70% to 100% block (all together), more SMEs (Estb. <5 years) lie in P field of >90% block, and lesser SMEs (Estb. <5 years) lie in L field of 71%–90% block.
- On an average, 71% of SMEs (Estb. <5 years) follow greater than 70% of SPs of CMMI Level II.

Summarizing for non-CMMI SMEs (Estb. <5 years)

- Follow-up of 90%–100% SPs by 53% to 67% of noncertified SMEs that are established for less than 5 years.
- Follow-up of 71%–100% SPs by 83% to 96% of noncertified SMEs that are established for greater than 5 years.

#### 4.4.1 | Statistical analysis and validation

Student's *t*-test is applied on the response set received from SMEs established for more than 5 years and SMEs established for fewer than 5 years following CMMI Level II PA–SPs set in different adoption brackets processes to evaluate the difference. Munro<sup>57</sup> and Cohen<sup>58</sup> elaborated *t*-test as a type of inferential statistic used to determine if there is a significant difference between the means of two groups, which may be related in certain features. Table 11 shows the result of Student's *t*-test statistic applied.

Pair 3 shows that there is no significant difference between the specific practices followed in SMEs (Estb. >5 years) and SMEs (Estb. <5 years) as calculated *t* value (sig. two tailed) is more than actual *t* value. This means more than 70% specific practices for respective PAs of CMMI Level II are followed by both types of organizations taken as a sample.

Pair 4 also shows that there is a significant difference between the specific practices followed in SMEs (Estb. >5 years) and SMEs (Estb. <5 years) as calculated *t* value (sig. two tailed) is less than actual *t* value. This means that SMEs (Estb. >5 years) follow greater than 90% of specific practices, whereas SMEs (Estb. <5 years) lie in the 71%–90% or lesser brackets.

#### 4.5 | CMMI Level III PAs and SPs

Table 12 depicts a number of responses received from CMMI Level III-based survey questionnaire. We have segregated the response according to the acceptance and adoption percentage as low (<50%), medium (50%–70%), high (71%–90%), and very high (>90%) for SPs of CMMI Level II processes and specific practices by noncertified SMEs.

We have formulated the RuleML described in Section 4.3.2 for the CMMI ML of a particular SME. According to the rule, a greater number of processes and SPs should lie in the high and very high zone as perceived value to achieve that particular CMMI maturity level. RuleML is based on the strategies followed by Wilkie et al.<sup>55</sup> and Iqbal et al.<sup>15</sup> with little modifications in percentages of specific practices followed in order to decide CMMI level of software organization that is not CMMI certified. RuleML follows the adoption percentage brackets for CMMI PA–SPs set given in Table 6 for the proposed approach. The threshold value is considered as more than 70% as per the exiting study by<sup>15</sup>.

##### 1 SMEs (Estb. >5 years)

- We have found while concentrating on the second last field, that is, Q, which is the sum of the two fields, J, and N, that 93% of SMEs followed greater than 70% of SPs for DAR processes in SMEs (Estb. >5 years). Similarly, for the processes IPM, OPD, OPF, OT, PI, RD, RSKM, TS, VAL, and VER, 86%, 96%, 80%, 93%, 77%, 86%, 93%, 83%, 93%, and 96% SMEs (Estb. >5 years), respectively, have been following greater than 70% of SPs of CMMI Level III processes.

**TABLE 11** *T*-test for CMMI Level II

SMEs in different adoption brackets	Differences				95% confidence interval of the difference		<i>t</i>	df	Sig. (two tailed)
	Mean	Std. deviation	Std. error mean		Lower	Upper			
Pair 1 SME (Estb. >5 years) – SME (Estb. <5 years) following <50% processes	–1.429	.976	.369	–2.331	–.526	–3.873	6	.008	
Pair 2 SME (Estb. >5 years) – SME (Estb. <5 years) following 50%–70% processes	–4.000	1.633	.617	–5.510	–2.490	–6.481	6	.001	
Pair 3 SME (Estb. >5 years) – SME (Estb. <5 years) following 71%–90% processes	0.000	.816	.309	–.755	.755	0.000	6	1.000	
Pair 4 SME (Estb. >5 years) – SME (Estb. <5 years) following >90% processes	5.714	1.604	.606	4.231	7.197	9.428	6	.000	

Abbreviations: CMMI, capability maturity model integration; df, degrees of freedom; Estb., established; SMEs, small and medium enterprises.

**TABLE 12** CMMI Level III PA-SPs with adoption percentage in SMEs established for more than 5 years and SMEs established for less than 5 years

PA	<50%				50%–70%				71%–90%				>90%				AVG	AVG
	SME >5 years		SME <5 years		SME >5 years		SME <5 years		SME >5 years		SME <5 years		SME >5 years		SME <5 years		SME >5 years	SME <5 years
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	%	%
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q = N + J	R = L + P
DAR	1	3	4	13	1	3	10	33	25	83	15	50	3	10	1	3	93	53
IPM	2	6	5	16	2	6	9	30	21	70	14	47	5	16	2	6	86	53
OPD	0	0	4	13	1	3	11	36	25	83	13	43	4	13	2	6	96	49
OPF	3	10	7	23	3	10	7	23	23	77	16	53	1	3	0	0	80	53
OT	1	3	4	13	1	3	8	27	23	77	14	47	5	16	3	10	93	57
PI	3	10	6	20	4	13	9	30	20	67	13	43	3	10	2	6	77	49
RD	2	6	6	20	4	13	7	23	22	73	16	53	4	13	1	3	86	56
RSKM	1	3	6	20	1	3	8	27	25	83	15	50	3	10	1	3	93	53
TS	2	6	5	16	3	10	7	23	23	77	14	47	2	6	2	6	83	53
VAL	1	3	6	20	2	6	9	30	22	73	14	47	6	20	1	3	93	50
VER	0	0	5	16	1	3	7	23	24	80	15	50	5	16	2	6	96	56
AVG%																	88	52

Abbreviations: CMMI, capability maturity model integration; DAR, decision analysis and resolution; IPM, integrated project management; OPD, organizational process definition; OPF, organizational process focus; OT, organizational training; PA, process area; PI, product integration; RD, requirements development; RSKM, risk management; SME, small and medium enterprise; SPs, specific practices; TS, technical solution; VAL, validation; VER, verification.

- These all are quite high figures and are appropriate to recognize that a good number of SMEs, which are established for greater than 5 years, are following at least 70% of the processes in CMMI Level III.
- It has also been found while concentrating on M field that number of SMEs (Estb. >5 years) following greater than 90% of the SPs of CMMI Level III lie in this field are quite low. In N field, only 3% to 20% SMEs (Estb. >5 years) are following greater than 90% of the SPs for CMMI Level II processes.
- It has been noted that 90% of the SPs are being followed in 3% to 20% of noncertified SMEs established for greater than 5 years.
- Focusing on J and N fields collectively, that is, 71% to 100% block (all together), more SMEs (Estb. >5 years) lie in P field of 71%–90% block and lesser SMEs (Estb. > 5 years) lie in L field of >90% block.
- On an average, 88% of SMEs (Estb. > 5 years) follow greater than 70% of SPs of CMMI Level III.

Summarizing in case of noncertified SMEs (Estb. >5 years)

- Follow-up of 90%–100% SPs by 0%–10% of noncertified SMEs that are established for more than 5 years.
- Follow-up of 70%–100% SPs by 80%–96% of SMEs that are established for more than 5 years.

## 2 SMEs (Estb. <5 years)

- Last field of Table 12, that is, R, gives the sum of L and P, which establishes that 53% of SMEs followed greater than 70% of SPs followed for DAR processes in SMEs (Estb. <5 years). Similarly, for the processes IPM, OPD, OPF, OT, PI, RD, RSKM, TS, VAL, and VER, 53%, 49%, 53%, 57%, 49%, 56%, 53%, 53%, 50%, and 56% SMEs (Estb. <5 years), respectively, have been following greater than 70% of SPs of CMMI Level III processes.
- Approximately 50% SMEs that are established for less than 5 years are following at least 70% of the processes in CMMI Level II.
- It has also been found while focusing on P field that a few numbers of SMEs (Estb. <5 years) are following greater than 90% of the SPs of CMMI Level III. SPs in DAR, IPM, OPD, OPF, OT, PI, RD, RSKM, TS, VAL, and VER in P field shows the percentage of SMEs (Estb. <5 years) are following 90% of the SPs for CMMI Level III processes is 3, 6, 6, 0, 10, 6, 3, 3, 6, 3, and 6, respectively. Zero percent of SMEs (Estb. <5 years) are following 90% of SPs for OPF. Ninety percent of SPs of IPM, OPD, PI, TS, and VER are followed by 6% of SMEs. OT for 90% of SPs is being followed by 10% of SMEs (Estb. <5 years). Only 3% SMEs (Estb. <5 years) follow greater than 90% SPs for DAR, RD, RSKM, and VAL.

- Though figures are not reaching high, it is very interesting to note the fact that 90% of the SPs are being followed in 0%–10% of noncertified SMEs established for less than 5 years.
- Focusing on P and L fields collectively, that is, 71% to 100% block (altogether), greater SMEs (Estb. <5 years) lie in P field of 71%–90% block and lesser SMEs (Estb. <5 years) lie in L field of >90% block for CMMI Level III.
- On an average, 52% of SMEs (Estb. <5 years) follow greater than 70% of SPs of CMMI Level III.

Summarizing the case of non-CMMI SMEs (Estb. <5 years)

- Follow-up of 90%–100% SPs by 0%–10% of noncertified SMEs that are established for less than 5 years.
- Follow-up of 71%–100% SPs by 83% to 96% of noncertified SMEs that are established for greater than 5 years.

#### 4.5.1 | Statistical analysis and validation

Student's *t*-test is applied on the response set received from SMEs established for more than 5 years and SMEs established for lesser than 5 years following CMMI Level II PA–SPs set in different adoption brackets processes to evaluate the difference. <sup>56</sup> elaborated *t*-test as a type of inferential statistic used to determine if there is a significant difference between the means of two groups, which may be related in certain features. Table 13 shows the result of Student's *t*-test statistic applied.

Pairs 1–4 show that there is a significant difference between the specific practices followed in SMEs (Estb. >5 years) and SMEs (Estb. <5 years) as calculated *t* value (sig. two tailed) is less than .05. Here, we can conclude from the consistent results of Tables 12 and 13 that only 53% of the specific practices are followed by SMEs established less than 5 years whereas 87% of the SPs of respective PAs of CMMI Level 3.

## 5 | RESULTS AND DISCUSSIONS

In the present study, we have calculated the average of the percentage response got for SPs followed for CMMI Level II and Level III processes. If the SME follows SPs for particular CMMI level process but these are less than 50% of SPs, then the response has been counted for <50% SP. Similarly, 50% to 70%, 71% to 90%, and >90% SPs blocks are created as shown in Table 12. The blocks are intentionally created in such a way that maturity levels could easily be identified according to RuleML. Those SMEs are a candidate to be counted for ML who follows at least 70% of the SPs in particular process. SMEs lying in <50% cannot be considered. As per the RuleML, considering high zone or block 71% to 90% SPs and very high zone or block, that is, >90% SPs together, more and more SMEs, that is, at least 70% SMEs, should lie in this region. This condition is taken into consideration in Table 14.

Figure 2 shows the average percentage of SMEs following SPs for CMMI Levels II and III with respect to year of establishment of SMEs, that is, less than or greater than 5 years.

Here, we can easily make out that SMEs (Estb. >5 years) have lesser intensity in <50% and 50%–70% region. For CMMI Level II, it is showing on an average 76% of the SMEs (Estb. >5 years) have accepted and followed greater than 90% of the SPs in CMMI Level II processes. According to the 70% rule, SMEs (Estb. >5 years) undoubtedly fall in CMMI Level II.

**TABLE 13** *T*-test for CMMI Level II

SMEs in different adoption brackets	Differences							
	Mean	Std. deviation	Std. error mean	95% confidence interval of the difference		<i>t</i>	df	Sig. (two tailed)
				Lower	Upper			
Pair 1 SME (Estb. >5 years) – SME (Estb. <5 years) following <50% processes	–3.818	.874	.263	–4.405	–3.231	–14.491	10	.000
Pair 2 SME (Estb. >5 years) – SME (Estb. <5 years) following 50%–70% processes	–6.273	2.149	.648	–7.716	–4.829	–9.681	10	.000
Pair 3 SME (Estb. >5 years) – SME (Estb. <5 years) following 71%–90% processes	8.545	1.753	.529	7.368	9.723	16.168	10	.000
Pair 4 SME (Estb. >5 years) – SME (Estb. <5 years) following >90% processes	2.182	1.328	.400	1.290	3.074	5.449	10	.000

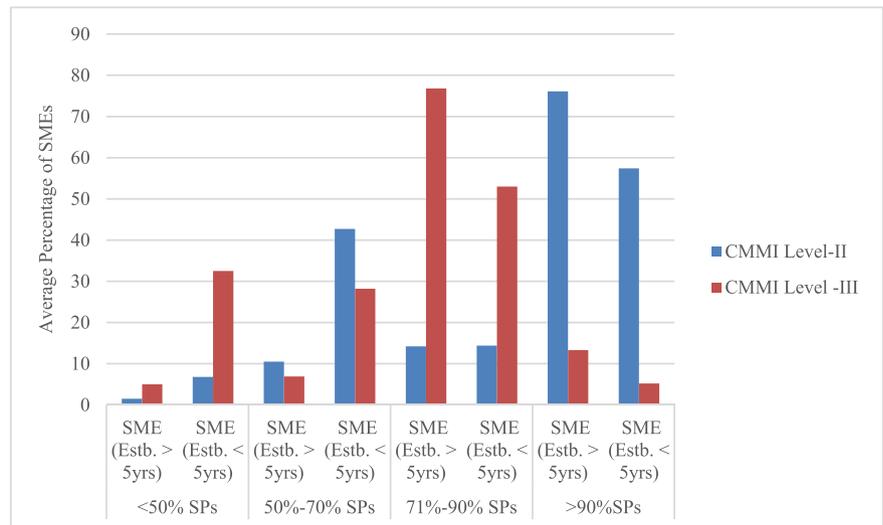
Abbreviations: CMMI, capability maturity model integration; df, degrees of freedom; Estb., established; SMEs, small and medium enterprises.

**TABLE 14** Percentage of CMMI PA-SPs followed by SMEs

Maturity level vs. time of establishment	<50% SPs		50%–70% SPs		71%–90% SPs		>90% SPs	
	SME (Estb. >5 years)	SME (Estb. <5 years)	SME (Estb. >5 years)	SME (Estb. <5 years)	SME (Estb. >5 years)	SME (Estb. <5 years)	SME (Estb. >5 years)	SME (Estb. <5 years)
CMMI Level II	1.5	6.8	10.5	42.7	14.2	14.4	76.1	57.4
CMMI Level III	5	32.5	6.9	28.2	76.8	53	13.3	5.2

Abbreviations: CMMI, capability maturity model integration; Estb., established; PA, process area; SMEs, small and medium enterprises; SPs, specific practices.

**FIGURE 2** Average percentage of SMEs following SPs for CMMI Levels II and III with respect to year of establishment. CMMI, capability maturity model integration; Estb., established; SMEs, small and medium enterprises; SPs, specific practices [Colour figure can be viewed at wileyonlinelibrary.com]



SMEs (Estb. <5 years) reach up to 57% in following >90% of the SPs in CMMI Level II. A total of 14% of SMEs followed SPs in 70%–90%. It clearly indicates on summing up 70–90 and above 90 block that 71% of the SMEs (Estb. <5 years) follow greater than 70% of the SPs of CMMI Level II. According to the RuleML, SMEs (Estb. <5 years) also fulfill the 70% rule. It can further be noted that 40% of the SMEs (Estb. <5 years) lie in 50%–70%. It is shown in Table 14.

## 5.1 | Final decision on assignment of maturity rating to non-CMMI SMEs

For assigning maturity rating informally, that is, without actual CMMI certification, we have worked according to the Criterion I and RuleML. Accordingly, happy face ☺ has been used to indicate that 70% rule, that is, RuleML is fulfilled, and sad face ☹ indicates the case if 70% rule, that is, RuleML is not fulfilled. It has been depicted in Table 15, and related findings have been discussed in the Section 6.1.1. The goal of the whole research has been quoted in Section 6.1.2 as the final decision on ML for non-CMMI SMEs.

70% rule or RuleML is fulfilled ☺.

70% rule or RuleML is not fulfilled ☹.

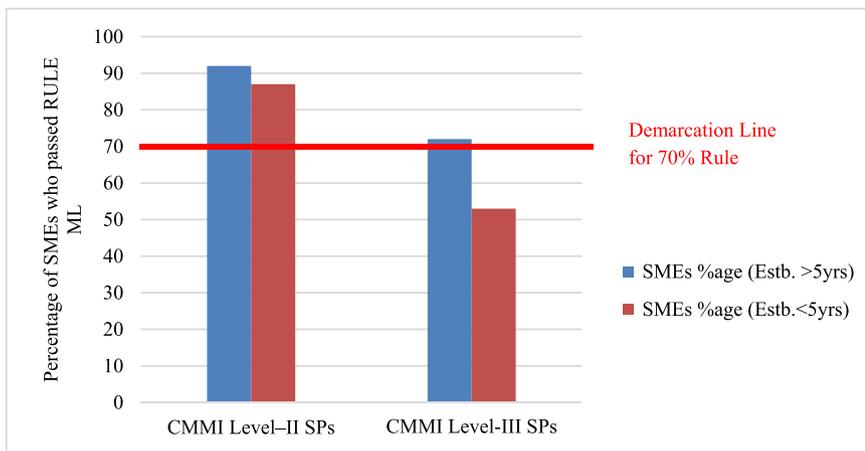
### 5.1.1 | Findings

- ☺ Approximately 91% SMEs (Estb. >5 years) followed greater than 71%–100% SPs at CMMI Level II.
- ☺ Approximately 71% SMEs (Estb. <5 years) followed greater than 71%–100% SPs at CMMI Level II.
- ☺ Approximately 88% SMEs (Estb. >5 years) followed greater than 71%–100% SPs at CMMI Level III.
- ☹ Approximately 52% SMEs (Estb. <5 years) followed greater than 71%–100% SPs at CMMI Level III.

**TABLE 15** Percentage of SMEs who passed RuleML

SPs for CMMI levels	SMEs percentage (Estb. >5 years)	SMEs percentage (Estb. <5 years)
CMMI Level II SPs	91 ☺	71 ☺
CMMI Level III SPs	88 ☺	52 ☹

Abbreviations: CMMI, capability maturity model integration; Estb., established; SMEs, small and medium enterprises; SPs, specific practices.



**FIGURE 3** Average percentage of SMEs following more than 70% of SPs for CMMI Levels II and III. CMMI, capability maturity model integration; Estb., established; SMEs, small and medium enterprises; SPs, specific practices [Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

### 5.1.2 | Final decision

- SMEs (Estb. >5 years) are at CMMI Level III informally.
- SMEs (Estb. <5 years) are at CMMI Level II informally.

## 6 | CONCLUSIONS

This section discusses the uniqueness of the research work with its limitations and future scope.

### 6.1 | Summary

The paper has been successful in its attempt to answer the laid research questions. It has made a commendable contribution by establishing the maturity rating unofficially on the basis of CMMI-DEV v1.3 for non-CMMI SMEs, that is, SMEs that are not certified by CMMI-DEV v1.3 but follow its practices informally. It differs from existing work<sup>15</sup> for the following reasons: (1) the time of establishment of SMEs was taken as an important parameter for ascertaining the CMMI maturity. (2) The present research work is important and different from others as there is no such existing study for Indian SME. It has also been made crystal clear that the time of establishment of SMEs has a significant role to play in gaining process maturity and related maturity rating. Important decisions have been taken on maturity rating according to the RuleML that is shown with the help of Figure 3. Figure 3 concludes the process maturity of SMEs on the basis of the time of establishment. It has also shown that SMEs (Estb. >5 years) have claimed CMMI Level III rating, whereas SMEs (Estb. <5 years) have claimed CMMI Level II rating according to RuleML or 70% rule. Above the demarcation line for 70% rule lie the SMEs who have CMMI Level II or CMMI Level III.

- SMEs (Estb. >5 years) and SMEs (Estb. <5 years) both have cleared the 70% rule to be rated at CMMI Level II.
- SMEs (Estb. >5 years) have cleared the 70% rule to be rated at CMMI Level III but SMEs (Estb. <5 years) have not cleared the 70% rule to be ranked for CMMI Level III.

It has been shown clearly that non-CMMI SMEs (Estb. >5 years) are at CMMI Level III and non-CMMI SMEs (Estb. <5 years) are at CMMI Level II. The appropriate authorities should focus on the SMEs that informally follow an adequate number of CMMI-based SPI practices.

We have validated the responses statistically using t-test, which is applied on the response set received. It showed that there is a significant difference in adoption percentages of practices followed in SMEs (Estb. >5 years) and SMEs (Estb. <5 years) for CMMI Level III. The same has been discussed in Sections 4.4.1 and 4.5.1. Tables 12 and 13 presents t-test for CMMI Levels II and III, respectively.

### 6.2 | Managerial implications

Indian software industry is an important sector for gross domestic product growth. So periodic evaluation of the achieved maturity level by non-CMMI SMEs is very crucial though unofficially. The informal or unofficial assignment of maturity rating to non-CMMI SMEs represent the status

of readiness of such SMEs for an official adoption of CMMI-DEV v1.3. The present study has answered many questions that previously remained unanswered regarding Indian software SMEs for a long time. This paper implies that Indian software SMEs have been following CMMI and accepted it though not officially but informally. These SMEs are continuously moving towards process improvisation and standardization. By achieving CMMI Level III informally, non-CMMI SMEs with more than 5 years of their establishment has suggested a positive move towards maturity. Indian software industry is no more immature. Indian software industry is progressing towards a new era. Time has been proved to be a crucial player in this scenario. SMEs (Estb. >5 years) has moved to CMMI Level III and present their candidature to achieve CMMI rating officially also. SMEs (Estb. <5 years) have achieved CMMI Level II informally and are able to work with the help of existing expertise in the software enterprise.

### 6.3 | Limitations of the research

The present research work is limited in its attempt due to the following reasons:

- The sample of the study may not be a representative of all the Indian regions. Demographically, Indian software industry is situated mostly in southern, central, northern, and western parts of India. Only a few SMEs are located in the eastern part of India. So the sample of this study does not cover the SEs from the eastern part of India.
- Internet era has emerged as a state-of-the-art information resource that can be used by SMEs for current SPI and CMMI-related needs. So the present study has not concentrated upon official adoption of CMMI.

### 6.4 | Future work

- The present study is confined to southern, central, northern, and western parts of India only. However, to corroborate and extend the outcomes of this study, an extensive research can be carried out with a larger sample covering different regions of the country.
- Because cultural, economic, social, and demographic differences exist among the small and medium scale software organizations of different countries and regions, therefore, it would be interesting to find whether the findings of this study are appropriate for other countries also. Thus, a follow-up study can be undertaken with respect to other countries.
- The present study can also be automated for the RuleML with more extensive data on SMEs. Non-CMMI SMEs data can be fed and RuleML can be applied to establish the maturity rating on a larger set of SMEs.

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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