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R3P2: A Performance Model For Readiness Review Process Improvement In Capability Maturity Model Integration Level 3

Tachanun Kangwantrakool[1], Thanaruk Theeramunkong[1], Sasiporn Usanavasin[1], Chayakorn Piyabundit[2]

[1]*Sirindhorn International Institute of Technology, Thammasat University, Thailand*
[2] *Institute of Software Engineering improvement and Quality Management, Bangkok, Thailand*
Email: tachanun990@gmail.com

Abstract

The evaluation of CMMI practice in an organization is complex and time-consuming, particularly the readiness review (RR) process; therefore, a precise and accurate assessment methodology and a systematic toolbox are required. This study introduces the Re-engineering Readiness Review Process Performance (R3P2) model, in which a set of performance measures is established and an integrated toolbox, the PPM Suite, is proposed. The model consists of (1) a document management tool for shared, reusable documents; (2) a project management mechanism to facilitate mapping between documents and CMMI practices; and (3) a set of metrics to standardize process improvement by providing a common understanding of how to define quality. The evaluation result on the real appraisals of 308 case studies in four primary and four secondary metrics demonstrates that our R3P2 models improve appraisal performance over the baseline, the non-IT version, by an average of 32.35 and 69.04 % for R3P2-2016 and R3P2-2017, respectively. In addition, the most recent version, R3P2-2017, outperforms its predecessor, R3P2-2016, by approximately 45.42 % on average and in the majority of metrics, including maturity level delivery, customer satisfaction, cycle time delay, and assessment gap, customer expectation, cycle time delay variability, and readiness review process capacity, with the exception of gap variability.

Keywords: R3P2 Model, CMMI Level 3, Readiness Review Process Improvement.

1. Introduction

In the past, organizations used process definition, documentation, self-evaluation, and formal appraisal to improve their processes [1, 2]. The Capability Maturity Model Integration (CMMI) and ISO/IEC 15504-2 (Software Process Improvement and Capability Determination, SPICE) are two of the most commonly used standard models for process improvement [3, 4]. The Standard CMMI Appraisal Method for Process Improvement (SCAMPI SM) is commonly used for evaluation within the CMMI model [5]. To acquire a better self-assessment and official appraisal process, it is necessary to avoid uncertainty, inadequacy, and immoderation in the process of ready review under the limits of time consumption and review quality, as defined by a gap between stakeholders. McFeeley (1996) [6] suggested IDEAL as a user guideline for software process improvement as an extension of the classic PDCA (Plan-Do-Check-Act) cycle created in the 1990s. The basic idea is to systematically gather and analyze data from the software process evaluation in terms of its strengths, flaws, and suggestions as the main assessment outcomes for planning improvement activities. This model appears to be time-consuming for the evaluation, despite its attempt to create thorough recommendations based on best practices. This is likely owing to the model's rigid formal approach. Later, a number of studies attempted to simplify the intense model for process appraisal in small businesses by adopting lightweight assessment techniques, such as those provided by Pino et al. (2010) [7] and Tang et al. (2012) [8]. Their goal is to address the difficulties of costly process assessment, excessive resource consumption, and insufficient data resulting from the assessment method's limited scope [9]. Recent research utilized a deep learning LSTM sequence model to estimate software project delay time from an unstructured software project description. So, a lightweight technique with a small number of case studies isn't very good at generalizing, and some biases may be caused by differences in geographical and organizational cultures, such as a certain way of managing events and data.

This paper proposed a model called Re-engineering Readiness Review Process Performance (R3P2), which uses a set of performance metrics and an integrated toolkit called the PPM Suite to solve the problem of an organization's CMMI practice appraisal being difficult and time-consuming. Estimation helps determine not just the required amount but also the time necessary to execute the project. Once we know how much it will cost in man-hours (effort unit) and all project dependencies, the time estimate may be simply converted into a budget. However, estimating the duration of a software project is a difficult process. It is a time-intensive endeavor that requires the expertise of software analysts. There have been several documented approaches for estimating the effort required for a software development project. The majority of them rely on rule-based decision making or past data. L.H. Putnam introduced the empirical approach for estimating computer software for the first time in 1978. Proposed is a macro approach that generates realistic estimates of people, costs, and durations required to fulfill important project milestones. The R3P2 model and PPM toolset can be utilized in each organization from the project's initiation to its conclusion, as per the intended outcomes. The recorded project data and documentation may be reused or repeated throughout the official readiness evaluation and assessment. How this information is utilized is up to the discretion of the leader. The three hundred and eight organizations included in this study have implemented the R3P2 model and PPM toolset as a result of the decision of the nine-lead assessor group to collect data. The R3P2 model has more advantages than the traditional readiness process (it is a one-time process), which is to collect the statistics of each organization's readiness review process into a large database. To evaluate the R3P2 model's user-friendliness and its capacity for further efficiency improvement.

2. Literature Review and Related Work

This section explains the general concept in the CMMI appraisal process where two types of stakeholders are involved; the five levels in the CMMI model, followed by gap definition in the readiness review process, and related work.

2.1 R3P2 model with Capability Maturity Model Integration

Al-Elaimat and Al-Ghuwairi (2015) [10] introduced agility into software quality model procedural assessment. This was done in 2015 to encourage quick and flexible assessment management for all organizations. The work only gave a rough idea of a procedural assessment process using agile practices to manage multimodal software development, improvement, and quality processes. The work achieved nothing else. PATECH [11], KNEUPER [12], SQI [13], and GRAFP [14] help standardize rapid and adaptable process evaluations. Most of these tools assume there is only one cycle in the evaluation process, despite the fact that each has its own benefits and drawbacks. CMMI ML3 includes process management, project management, engineering, and support subsystems. Evaluation at maturity level 3 indicates "defined" standard process. This means the organization's processes are defined according to international standards, procedures, tools, and methodology. At level 3, the organization has established its own standard processes, which are continuously improved to ensure the delivery of a quality product that inspires confidence in both its development and delivery. CMMI ML3's process appraisal methodology and supporting tools are in high demand. Kangwantrakool and Theeramunkong (2017) [15] proposed an R2P2 model to improve CMMI readiness review processes. This was done to design a performance model and supporting tools. Despite being an early version of the model, it was still worth exploring flexibility. The design was created after researching the typical challenges faced by an internal team and an appraisal team, as well as their approaches to addressing discrepancies in their respective evaluations. [16, 17]. A number of reports on process performance improvement [18–20] cite the tedious appraisal process and the appraisal score mismatch between the internal team (IT) and the appraisal team (AT). Several papers [2, 20–25] propose different metrics. The R3P2 model provides performance metrics for measures of the readiness review process so that the capability of the RR process can be calculated using the Six Sigma process, assuming the data follows a normal probability distribution [23, 26]. The R3P2 model supports the onsite CMMI readiness review process. This model helps internal and external appraisers.

2.2 Gap Definition in Readiness Review Process (RR)

In the Readiness Review Process (RR) towards CMMI appraisal, the main stakeholders are categorized into two groups: (1) the internal team (IT) and (2) the appraisal team (AT). IT includes internal team members from the target company, such as the organization’s software engineering process group (SEPG) and/or quality assurance group (QA). AT specifies a set of appraisal team members who are elected to perform cross-checking of all objectives (i.e., acceptable verified documents) evidence (OE). In an appraisal, an assessment gap is usually defined in terms of how many specific practices that IT and AT disagree on the existence of weaknesses. More specifically, an agreement or a disagreement is investigated for each specific practice in the pre-defined set [5]. Before the official appraisal, the RR process is usually performed to check the readiness level. For both the RR process and the official appraisal, the target company has to set up its CMMI model component for eighteen process areas using the templates. The gap derives from the cumulative gap counts of all sub-practice’s activity of a generic or specific practice by investigating and then assessing evidences that are in the form of typical work products.

3. Methodology

This section describes the following aspects of the research design: describes the work done in conjunction with the R3P2 model. The author proposed the R3P2 model, which is structured as follows, for this primary research.

3.1 A Framework of the R3P2 Model Development

This section describes the R3P2 framework. The framework includes 308 three-phase appraisals. From 2010 to 2015, 168 conventional readiness reviews were conducted. The 70 second-phase appraisals were conducted in 2016 when the R3P2 model with performance metrics was developed using the PPM Suite version 1.0. The last phase was organized in 2017–2018 using the R3P2 model supported by PPM Suite 2.0, the software or application. Figure 1 shows the PPM Suite toolset's R3P2 framework. The figure shows eight steps in the framework, from the conventional RR process to the final repository, or process performance baseline. A rounded rectangular represents a process, a rectangular an output, and a cylinder an appraisal record or performance baseline. Below are details on three framework appraisal phases.

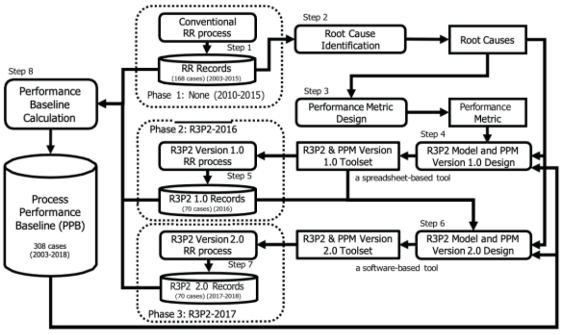

Figure 1 A framework of developing the R3P2 model supported by the PPM Suite toolset

3.2 Performance Metrics

Our designed metrics are related to IT and AT appraisal activities, where the related measures are kept as appraisal records for analysis. Using existing techniques and metrics [10, 20–28] in statistical process control, we propose four primary and four secondary metrics for the readiness review process. In the RR process, the criteria for an efficient appraisal process are to shorten the appraisal process [29–32] and to reduce the gap (or disagreement) on the result between the company's internal audit team and the appraisal team [33, 34]. The criteria for an effective process are to increase customer satisfaction [35] and to raise the success rate of maturity level delivery [36, 37]. Based on these four criteria, R3P2 proposes four primary metrics. In an efficient process, cycle time delay and assessment gap should be low. Effective processes should have high maturity levels of delivery and customer satisfaction. The appraisal records contain these primary metrics. We also created four secondary metrics derived from the primary metrics. Secondary metrics are quality appraisal measures. Customer expectation is the first secondary metric and is derived from maturity level delivery, customer satisfaction, and cycle time delay [38]. A larger value for this metric indicates a better result. Variability of cycle time delays and gaps are secondary metrics. According to ISO 5725-1:1994 [39], cycle time delay and gap represent the truth while their variability expresses precision. Delay-related metrics are negative, so a lower value is better. The fourth secondary metric is RR process capability [24–28, 40].

3.3 Description of the R3P2 Model

This section describes the R3P2 model and its use to monitor and improve RR process performance using the previously described metrics. Figure 2 depicts the R3P2 model with its two main components, RR and model performance. In the RR process (left side of figure), IT and AT independently investigate and verify document inventory.

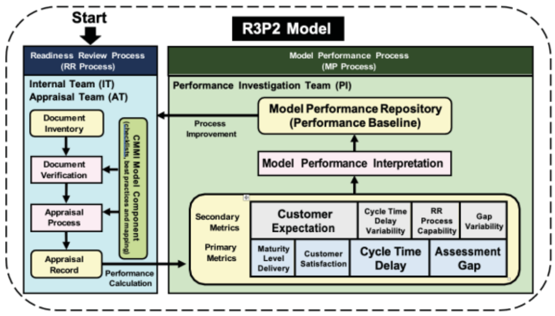

Figure 2 The R3P2 Model Description

The CMMI model component includes checklists of tasks to execute and documents to verify; best practices as examples; and their mapping. It or AT evaluates the inventory documents using document checklists and best practices. IT and AI results are used for appraisal and performance calculations. In the model performance process, four primary performance metrics are calculated and then used to derive four secondary metrics. The database stores model performance metrics. The interpreted results will be used to develop a plan to improve RR performance.

3.4 The PPM Suit: An integrated tool for R3P2

Along with our suggested R3P2 architecture, we built the integrated tools, namely the Project Performance Managing Suite (PPM Suite). The first version of the PPM Suite was created using simple standalone word processing, spreadsheet, and presentation apps, i.e. Microsoft Word, Excel, and PowerPoint. Later, the second version was launched with the redevelopment of the toolset as an application based on the first. The particulars are provided in the subsequent section, Figure 3 depicts, on the left, the main page of the PPM Suite Version 2.0, which consists of eight buttons for eight operation modules, and, on the right, a snapshot of the PPM Suite's assessment assistance page when the fourth button is hit.

Each module consists of a few sub-modules with a few functionalities. Figure 4 enumerates the complete lists of modules, sub-modules, and functions. The first button, Organization Data Settings, allows us to set the organization (corporation), project management, and quality assurance (QA) profile settings. The second button, Project Management, takes us to a page that comprises project initiation, project monitoring and control, and project closing in order to manage a project.

Project Performance Management (PPM)
1 Organization Data Settings
1.1 Organization Settings
1.1.1 Role & Responsibilities Settings
1.1.2 Staff/User Profiles Settings
1.1.3 Cost Settings
1.1.4 Risk Repository
1.1.5 Lesson Learn Repository
1.1.6 Organization Training Settings
1.2 Project Management Settings
1.2.1 Project Type Settings
1.2.2 Project Estimation Criteria Settings
1.2.3 SDLC & Phase Settings
1.2.4 Worktype Settings
1.2.5 Process Settings
1.3 QA Settings
1.3.1 Process V&V Checklist Management
1.3.2 Quality Assurance (QA) Planing
1.3.3 Quality Assurance (QA) Checklist Evaluation
1.3.4 Quality Assurance (QA) Checklist Reports
2 Project Management
2.1 Project Initialization
2.1.1 Project Informaiton & Staff Settings
2.1.2 Project Estimationn
2.1.3 Process Tailoring Settings
2.1.4 Project Planing
2.1.5 Quotation Management
2.2 Project Monitoring and Control
2.2.1 Project Task Management
2.2.2 Project Timesheet
2.2.3 Project Status Report
2.2.4 Task Verification
2.3 Project Closure
2.3.1 Project Lesson Learn Management
2.3.2 Project Closure & Knowledge Transition
3 Project Management Support
3.1 Change Management
3.1.1 Change Request & Approvall Records
3.2 Risk Management
3.2.1 Project Risk Management
3.3 Decision Analysis & Resolution
3.3.1 Decision Analysis Trigger
3.3.2 Decision Metrics & Action Plan
3.4 Organization Training Management
3.4.1 Organization Training Records

Project Performance Management (PPM) (Continued)
4 CMMI Appraisal Assistance
4.1 Project Evidence List
4.1.1 Evidence Gathering
4.1.2 Evidence Cross-instantiation
4.2 Evidence Coverage Review
4.2.1 Work Package 1
4.2.2 Readiness Review Metrics
4.3 Summary & Rating
4.3.1 Evidence Summary Report
4.3.2 CMMI Goal Rating
4.3.3 CMMI Process Area Rating
4.3.4 CMMI Organization Unit Maturity Rating
4.3.5 Review CMMI Appraisal Results
4.3.6 Appraisal Metrics
5 Quality Management
5.1 Quality Assurance (QA) Planing and Inspection
5.1.1 QA Setup Plan
5.1.2 Defect Inspection Log
5.3 Process Improvement
5.3.1 Projects Lesson Learnt
5.3.2 Software Process Improvisation (SPI) Program
6 Document Management
6.1 Checklist and Best Practice Management
6.2 Document Evidence Management
6.3 Project Document Repository and Progress Report
7 Model Project Management
7.1 Objective & KPI Setup
7.1.1 Objectives
7.1.2 KPIs for Improvement
7.1.2 KPIs related Formula
7.2 Process Baseline
7.2.1 Report of all Appraisal Profiles
7.2.2 Export to Excel
7.3 Model Perforamcence Indicators and Dashboard
7.3.1 Maturity Level Delivery
7.3.2 Customer Satisfaction
7.3.3 Cycle Time Delay
7.3.4 Assessment Gap
7.3.5 Customer Expection
7.3.6 Cycle Time Delay Variability
7.3.7 Quality (Gap) Variability
7.3.8 R3P2 Process Capability
8 User Manual
8.1 Manual for Internal Team, Appraisal Team, and Managers

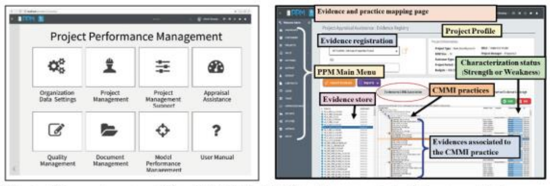

Fig 4. The main page of the PPM Suite (left) and a snapshot of the appraisal assistance page of the PPM Suite (right)

Figure 3 The main page of the PPM Suit (left) and a snapshot of the appraisal assistance page of the PPM Suit (right)

Figure 4 Three layers in the PPM Suit: modules, sub-modules, and functions

In addition, a project dashboard is offered to provide an overview of the project's progress and overall performance. As the third button, Project Management Support offers us with the capabilities to manage change and risk, conduct decision analysis and resolution, and manage organizational training. In addition, it permits exporting data to an Excel file, which may be used by subsequent users to generate any chart they desire. Appraisal Assistance, the fourth button, activates a tool that assists users in tracking the level of satisfaction and maturity against the CMMI standards.

3.5 The R3P2 Model Deployment

This section describes the deployment of R3P2 and how it was used to improve continuous readiness review. In three different environments, appraisals were performed and their activities and performance records were collected to improve the appraisal process and performance analysis. The first environment collects appraisal records where R3P2 and an IT tool were not used, the conventional RR process. In the second environment, appraisal records were filed when R3P2 was implemented as a spreadsheet, or version 1.0. The PPM Suite was used to track the R3P2 model evaluations in the third environment. This model is R3P2 2.0.

No.	Process/Function	Conventional RR process	R3P2 Version 1.0	R3P2 Version 2.0
1	Provision of direct artifacts of specific / generic practices	None	Common direct artifacts and practices mapping were provided	*Common direct artifacts and practices mapping were provided*
2	Document review guideline	Exist but simple	Verification checklists of associated artifacts for each practice were provided	*Verification checklists of associated artifacts for each practice were provided*
3	Justification	Manual/ Subjective	Semi-systematic criteria for justification were provided	*Semi-systematic criteria for justification were provided*
4	Process Performance Assessment	none	Statistical data procedure & criteria were proposed with process performance modeling	*Statistical data procedure & criteria were proposed with process performance modeling*
5	Template Provision	none	Best practices and templates were provided	*Best practices and templates were provided*
6	Data inventory	Manual	PPM Suite version 1.0	*PPM Suite version 2.0*
7	Document Management	none	none	*Document inventory and control were implemented*
8	Project Management	none	none	*Project lifecycle associated documents to CMMI practices was implemented*
9	Process Improvement Management	none	none	*Appraisal process data were collected and used for process improvement*

Figure 5 Evolution of the R3P2 models, comparing the R3P2 version 1.0 and 2.0

Compare these three environments in Figure 5. The conventional RR process is mostly manual, but R3P2 versions 1.0 and 2.0 provide checklists, explicit criteria and procedures, best practices, templates, and a toolset for automating sub-processes in the appraisal process. The R3P2 version 1.0 toolkit is a set of spreadsheets that coordinate the appraisal process semi-automatically or automatically. First attempt to provide IT and AT teams with guidelines, evidence list control, semi-systematic justification including model performance metrics, and process performance assessment support. Later, R3P2 version 2.0 was created as a software-based process where the toolkit is an application created with lessons from R3P2 version 1.0. Document management, project management, and process improvement management are also in 2.0.

4. Result and Discussion

4.1 Performance Analysis and Comparison

This section illustrates the performance results before and after the deployment of the R3P2 models in the three appraisal environments shown in the previous section. The appraisals under the three environments (2010–2015, 2016, and 2017) were obtained from 168, 70, and 70 cases, for a total of 308 cases, collected from the assessment of organizations by nine experts in five continents: 138 Asia, 91 Europe, 52 North America, 19 South America, and eight Australian organizations. The appraisals were done by the nine experts, whose characteristics are shown in Figure 6. In the table, "EID" = expert ID, "License" = the CMMI institute's license, "Education" = education background (M = Master's degree, D = Doctoral degree), "Engineer" = engineer experience (years), "Manager" = managerial experience (years), and "Life" = life cycle experience (full = full life cycle). For 'Application Domain', 'Fi' = financial and accounting, 'Te' = telecommunication, 'Ed' = education, 'Go' = government, 'He' = healthcare, 'Le' = legal, 'In' = industrial engineering, 'Ma' = marketing. As the appraisal teams, they hold the CMMI Institute's license as SCAMPI lead appraisers (cmmiinstitute.com) with 15–25-year experience in engineering tasks and 6–19-year experience in management tasks. Their educational background is either a master's degree or a doctoral degree.

EID	Expert Characteristics					Application Domain							
	License	Education	Engineer	Manager	Life	Fi	Te	Ed	Go	He	Le	In	Ma
1	Yes	D	20	7	Full	0	0		0	0	0	0	0
2	Yes	D	18	6	Full	0	0	0	0	0	0	0	0
3	Yes	D	16	6	Full	0	0	0	0	0	0	0	0
4	Yes	D	15	6	Full	0	0	0		0	0	0	0
5	Yes	D	15	5	Full	0	0	0	0	0	0		
6	Yes	M	25	11	Full		0	0	0	0		0	
7	Yes	M	23	19	Full	0	0	0	0	0			0
8	Yes	M	21	14	Full	0	0	0	0	0			0
9	Yes	M	20	12	Full	0	0	0	0	0	0	0	0

Figure 6 Characteristics of the appraisal exerts

Recall the R3P2 model and eight metrics in Figure 2. The R3P2 model contains two parts: the RR process and the model performance process. Our assumption is that the model performance can be improved using the R3P2 model and its facilitating PPM.

4.2 Questionnaire Survey during Root Cause Analysis

Recall the relationship matrix between major problems in the traditional RR process, the proposed causes/solutions and their activities were analyzed. The causes are classified into five categories (C1-C5) while the problems are arranged into three levels: document handling

(D), knowledge management (K), and managerial mechanisms (M). The author designed the questionnaire scores for the five causes and the three problem levels. A survey questionnaire was given to a company manager, an internal team, and an evaluation team from each of the organizations that took part. The value expresses the level of agreement, whether the sub-process solves the problem or not. The result shows that we obtain a much higher score when the R3P2 is implemented. The R3P2 improves the performance of all levels of problems, including document handling (D), knowledge management (K), and managerial mechanisms (M), as well as in all sub-processes. From the table, R3P2-2016 and R3P2-2017 were evaluated to help improve document handling from 19.40% to 81.77% and 88.51%, respectively. For knowledge management, R3P2-2016 and R3P2-2017 increased the score from 19.16% to 81.29% and 89.52%, respectively. As for the managerial mechanism, R3P2-2016 and R3P2-2017 raised the score from 19.11% to 82.89% and 89.18%, respectively. The stakeholders' evidence showed that R3P2-2016 and R3P2-2017 helped solve all causes (C1-C5) of problems in the appraisal process. R3P2-2016 and R3P2-2017 increased the overall score by nearly 19% and 90%, respectively.

4.3 Comparative Result on Primary Metrics

This section analyzes the performance of the three settings in regard to the four most essential metrics, which are (P1) Maturity Level Delivery, (P2) Customer Satisfaction, (P3) Cycle Time Delay, and (P4) Assessment Gap. Figure 7 gives an overview of each statistic and each of its sub-metrics for each of the four sessions.

Primary Performance Metric	None (2010-2015)	R3P2-2016	R3P2-2017
P1: Maturity Level Delivery			
ML3 and ML2 are satisfied	86.31% (145/168)	88.57% (62/70)	90.00% (63/70)
Only ML2 is satisfied	11.90% (20/168)	10.00% (7/70)	10.00% (7/70)
ML2 is unsatisfied	1.79% (3/168)	1.43% (1/70)	0.00% (0/70)
P2: Customer Satisfaction			
Satisfied % (cases/total)	44.64% (75/168)	70.00% (49/70)	78.57% (55/70)
Necessity	75.48	82.29	89.71
Objective	65.95	77.43	76.00
Accuracy	81.90	85.43	91.71
Expectation	83.93	84.29	79.43
Team's performance	78.57	73.14	81.14
Team Leader's performance	81.67	80.00	78.29
Sponsor involvement	59.29	68.57	79.43
Improvement guidance	86.31	89.71	88.86
Implementation confidence	83.10	90.86	92.86
Appraisal quality	75.00	85.71	86.00
Average satisfaction score	77.12	81.74	84.34
P3: Cycle Time Delay (days)			
Plan (IT)	45.79±13.13	45.83±11.37	46.06±12.92
Actual (IT)	63.88±37.46	39.44±18.09	34.19±16.83
Total delay (IT)	21.72±33.35	3.91±10.58	1.97±3.65
Plan (AT)	40.67±11.05	41.83±9.55	41.26±10.23
Actual (AT)	48.79±13.92	33.66±13.34	36.13±14.49
Total delay (AT)	8.13±8.86	3.47±8.52	2.04±3.18
P4: Assessment Gap			
Missing weakness (IT)	1.69±1.55	4.10±3.21	3.34±2.41
Misinterpretation weakness (IT)	1.36±1.47	2.69±2.42	2.44±2.15
Total weakness (IT)	3.05±2.63	6.79±5.39	5.79±4.35
Missing weakness (AT)	4.80±4.17	4.20±3.09	2.31±1.63
Misinterpretation weakness (AT)	5.70±3.41	4.23±2.74	2.87±2.08
Total weakness (AT)	10.51±5.27	8.43±4.33	5.19±2.43
Missing Gap	3.47±3.39	3.70±2.47	2.31±1.71
Misinterpretation Gap	4.55±3.29	3.20±2.22	2.49±1.70
Total gap	8.02±4.50	6.90±[illegible]	4.80±2.49

Figure 7 Comparison of the three environments on the four primary metrics

4.4 Comparative Result on Secondary Metrics

This section analyzes the performance of the three settings in regard to the four most essential metrics, which are (S1) Customer Expectation, (S2) Cycle Time Delay Variability, (S3) Gap Variability, and (S4) R3P2 Process Capability. Figure 8 gives an overview of each statistic and each of its sub-metrics for each of the four sessions.

Secondary Performance Metric	None (2010-2015)	R3P2-2016	R3P2-2017
S1: Customer Expectation			
Maturity Level Delivery (MD)	86.31	88.57	90.00
Customer Satisfaction (CS)	44.64	70.00	78.57
Cycle Time Delay (CD)	42.74	81.86	80.57
Customer Expectation (CE)	57.90	80.14	83.05
S2: Cycle Time Delay Variability			
CT Delay (IT)	21.72±33.35	3.91±10.58	1.97±3.65
CT Delay (AT)	8.13±8.86	6.11±9.57	2.04±3.18
CT Delay Variability (IT)	1.54	2.70	1.85
CT Delay Variability (AT)	1.09	1.57	1.56
S3: Gap Variability			
Missing Gap (IT)	3.47±3.39	3.70±2.47	2.31±1.71
Misinterpret Gap (AT)	4.55±3.29	3.20±2.22	2.49±1.70
Total Gap (IT)	8.02±4.50	6.90±3.51	4.80±2.49
Missing Gap Variability (IT)	0.98	0.67	0.74
Misinterpret Gap Variability (AT)	0.72	0.69	0.68
Total Gap Variability (IT)	0.56	0.51	0.52
S4: R3P2 process capability			
RR Process Capability - CD-IT (Cp)	*0.12	*0.20	*1.24
RR Process Capability - CD-IT (Cpk)	*-0.02	*0.16	*0.24
RR Process Capability - CD-AT (Cp)	*0.38	*0.47	*0.86
RR Process Capability - CD-AT (Cpk)	*0.35	*022	*0.23
RR Process Capability - Gap (Cp)	*0.31	*0.50	*0.74
RR Process Capability - Gap (Cpk)	*0.12	*0.31	*0.71
RR Process Capability - CD-IT (Cp)	*0.27	*0.67	*0.68
RR Process Capability - CD-IT (Cpk)	*0.22	*0.25	*0.26
RR Process Capability - CD-AT (Cp)	*0.48	*0.59	*0.52
RR Process Capability - CD-AT (Cpk)	*0.39	*0.25	*0.27
RR Process Capability - Gap (Cp)	*0.13	0.57	0.75
RR Process Capability - Gap (Cpk)	*-0.24	0.31	0.71

Figure 8 Comparison of the three environments on the four primary metrics

4.5 Model Performance Interpretation

This section summarizes the results and gives comparison-based insights. In conclusion, we must consider (1) magnitude and (2) measure range. Smaller-is-better (S) and larger-is-better (L) are two first-dimension magnitude categories. Some second-dimensional measures are bound between 0% and 100%, while others have no limit. To normalize the range for better representation, we set the lower bound to zero (i.e., negative values are mapped to zero) for all unbound measures and the upper bound to 25, 10,10, 3, 3, 1 for IT cycle time delay, AT cycle time delay, assessment gap, IT cycle time delay variability, AT cycle time delay variability, and gap variability, and then interpolate the value. We set RR's upper bound to 100 without interpolation. Inverting the value by subtracting 100 for the smaller-is-better metric. The leftmost three columns show the transformed normalized values that make all metrics between 0 and 100. Larger values mean better methods.

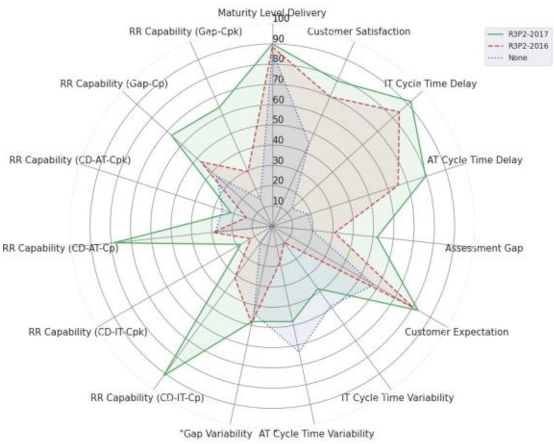

Figure 9 A radar chart visualizing the values of the fifteen metrics (five primary and ten secondary metrics enhanced from four primary and four secondary metrics).

Figure 9 shows the radar chart for 15 normalized metrics. The 15 metrics below summarize R3P2's strengths and weaknesses. R3P2-2017 outperforms R3P2-2016 in all metrics. R3P2 implementation improves the version without R3P2 (none) in almost all metrics, except IT cycle time variability, AT cycle time variability, and CD-IT RR process capability. Implementing R3P2 in a company may affect how unfamiliar internal and appraisal team members use it, causing variation between companies. The appraisal team can do well without R3P2, and the current model can be improved by training on R3P2 tools. Third, delivery maturity and gap variability are similar. With or without R3P2, maturity level delivery has stable gap variation. R3P2-2017 and R3P2-2016 beat zero. R3P2 can improve the internal team's IT cycle time delay, AT cycle time delay, and readiness review process capability. Fifth, both the internal team (CD-IT-Cp) and the appraisal team's RR cycle time delay capability has improved. Sixth, R3P2 improves RR's assessment gap capability (Gap-Cp). R3P2's performance is promising, and it's still improving.

5. Conclusion and Future work

This paper outlines the R3P2 strategy to enhance the CMMI assessment process, specifically the readiness review (RR), by using the PPM Suite and our proposed model performance. The PPM Suite supports three primary sub-processes to ease RR for CMMI novices: document verification, appraisal procedure, and model performance interpretation. In document verification and appraisal, the relationship matrix between traditional RR key issues, proposed solutions, and their activities was studied using 168, 70, and 70 appraisals. The first 168 examples used no R3P2 (none), the second 70 used R3P2-2016, and the last 70 used R3P2-2017. Based on these data, three sub-processes and three layers of concerns were analyzed: document handling, knowledge management, and managerial procedures. The most challenging issue was the managerial mechanism level, but R3P2 improved document handling and knowledge management also. The model performance interpretation supported a holistic analysis of the appraisal score in four primary metrics: maturity level delivery, customer satisfaction, cycle time delay, and assessment gap; and four secondary metrics: customer expectation, cycle time delay variability, readiness review process capacity, and gap variability. R3P2 performed well across most criteria. In future work, we plan to improve the R3P2 model and the PPM suite tool and tackle the cycle time variability of internal teams, assessment teams, and RR processes. While CMMI V1.3 will be sunset at the end of September 2020, the main technique in this paper can be applied to CMMI V2.0. We plan to adapt this paper's conclusions to CMMI 2.0. The study of evaluation outcomes may take 5–10 years because the data is not available. In the future, when the toolkit and/or appraisal help system are fully established, each appraisal activity can be measured in an hour unit. With these parameters, we can figure out how long each readiness review activity takes in hours and make a performance model that is more accurate.

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