

# A Case Study of Software Process Improvement Based on CMMI Ver 2.0

Wahyu Tri Anggoro, Sun-Jen Huang, Yulianus Palopak

**Abstract**—Most businesses rely heavily on software to properly function their business process. As a result, many businesses attempt to meet their needs by developing and customizing their software. However, many organizations face difficulties in the software development process. Effective software development is necessary to produce good quality software by finishing on time, being cost-effective, and following user requirements. CMMI-Dev version 2.0 is a framework that can be used to improve the quality of the software development process. This research aims to develop recommendations that can improve software quality based on the application of CMMI-Dev. Utilizing the case study approach in the banking industry, this study proposes a recommendation to improve software quality. The recommendation is based on CMMI-Dev version 2.0 as the practice area is chosen according to the selected CMMI roadmap and implements a final recommendation to improve the quality of its software process.

**Keywords**—CMMI, CMMI-Dev, CMMI Roadmap, CMMI Continuous Representation, Software Process Improvement, Software Quality Improvement.

## I. Introduction

Information technology has enabled a company to run its business in the information age. Software has become one of the primary needs of an organization as a tool to support and simplify business processes. Some businesses prefer to develop their own software to make it more adaptable to their requirements. Therefore, the organization needs the software development process to accelerate the achievement of business goals. The software development process is a stage to create software divided into several regular and structured stages. According to Sommerville [1], the definition of the software development process is a series of activities that are interrelated with each other and aimed at producing software products.

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Wahyu Tri Anggoro  
National Taiwan University of Science and Technology  
Taiwan

Sun-Jen Huang  
National Taiwan University of Science and Technology  
Taiwan

Yulianus Palopak  
National Taiwan University of Science and Technology  
Taiwan  
edu

Several models for these processes describe approaches to various tasks or activities [2], including requirements analysis, planning, design and implementation, testing, training and support, and maintenance.

The success of a software development process can be measured from three aspects, namely time, cost, and scope [3]. Software development can be successful if completed on time, cost-effective, and following user needs. However, a lot of development software is not finished on time; this will disrupt an organization's business process. The main problem that occurs when developing software is that the quality of the products produced does not meet expectations. The problem can be seen in that much software is not finished on schedule. Therefore, evaluating and providing recommendations for improving the software development process is necessary. Therefore, this study is eager to answer the research question:

- Based on CMMI-Dev 2.0, how to select the practice area that will be the improvement target?
- Based on CMMI-Dev 2.0, what recommendations are needed to improve the software development process in Bank XYZ?

This research aims to develop recommendations that can improve the quality of the software produced based on the application of CMMI-Dev. CMMI-Dev (Capability Maturity Model Integration for Development) is a framework issued by SEI (Software Engineering Institute) [4] that can be used to measure the maturity level of the software development process and help organizations improve the work process of a project, especially projects related to software. Using the CMMI Roadmap, an organization is expected to receive directions on implementing CMMI that suits the organization's requirements. The final result of this study is the proposal to improve the software development process based on the CMMI framework. Implementing the recommendations made is expected that it will improve the software development process in the company.

## II. Literature Review

### A. *Capability and Maturity Model*

CMMI-Dev (Capability Maturity Model Integration for Development) is a framework issued by SEI (Software Engineering Institute) [4]. CMMI-Dev is a framework that can be used to measure the maturity level of the software development process. CMMI-Dev can be used to help organizations improve the work process of a project, especially projects related to software.

## B. CMMI Representation

Two representations are used to implement CMMI: staged and continuous. The staged representation is the implementation of CMMI by following staged guidelines that SEI has published. The continuous representation is the implementation of CMMI by selecting the process area considered most needed by the organization. Stage representation is the most commonly used, although continuous representation is considered a more flexible option [5].

The staged representation of CMMI organizes process areas into five maturity levels: (ML 1), managed (ML 2), defined (ML 3), quantitatively managed (ML 4) and optimizing (ML 5). It illustrates the developments in software development, starting with standard improvement processes and advancing through a predefined and established collection of consecutive stages [6].

The continuous representation of a CMMI model consists of five categories—Project Roadmap, Product Roadmap, Product Integration Roadmap, Process Roadmap, and Measurement Roadmap [5]. Continuous representation allows software companies to select process areas they wish to improve and select the order that best meets their business goals or reduces the risk [6].

## C. CMMI Roadmap

CMMI Roadmap’s concept proposed by [5] was to figure out which process area should first be operated. They perform this by grouping the corresponding and related process areas, identifying the issues they want to address, and determining the objectives they want to achieve. Using the CMMI Roadmap, an organization is expected to receive directions on implementing CMMI that suits the organization’s requirements. CMMI Roadmap is based on CMMI Version 1.3. CMMI Roadmap on CMMI Version 2.1 required mapping between process areas on CMMI Version 1.3 with practice areas on CMMI Version 2.0. There are currently five roadmaps for CMMI: Project Roadmap, Product Roadmap, Product Integration Roadmap, Process Roadmap, and Measurement Roadmap. Each roadmap has different process areas [5].

# III. Research Methodology

## A. Case Study

This research investigates problems in the IT Division of Bank XYZ and seeks solutions to overcome them. Information is first needed on the organizational structure and the company’s business process (software development process).

IST division at Bank XYZ has never carried out CMMI assessments. Therefore, it is not yet known that the practice area needed to improve the quality of organizational process software. CMMI implementation begins by determining the

objective and problem which currently exists in an organization. This research uses continuous representation to implement CMMI. Therefore, a method or approach is needed to determine the required practice area. This objective and problem will become an input to determine the critical practice area. The authors use the CMMI Roadmap [5] in this research to determine the selected practice area.

The authors use CMMI Model 2.0, which was released by CMMI Institute in 2018, as a framework used in research. The SCAMPI (SCAMPI Team & CMMI Institute, 2014) [7] method is used to do the assessment, which was proposed by [8]. The results of this assessment are in the form of practices that have been satisfied and which have not been satisfied. The recommendations are arranged based on practices that have not satisfied with CMMI’s practice area. Other recommendations are based on factors hindering CMMI’s implementation in the organization [9]. The methodology for software development, which is currently in use, will also become a factor in determining the final recommendations for this research.

## B. Research Stage

In this research, the author arranged the stages of research using the IDEAL framework. Based on its name, the IDEAL framework consists of 5 phases, including Initiate, Diagnose, Establish, Action, and Learning. Fig. 1 describes the IDEAL

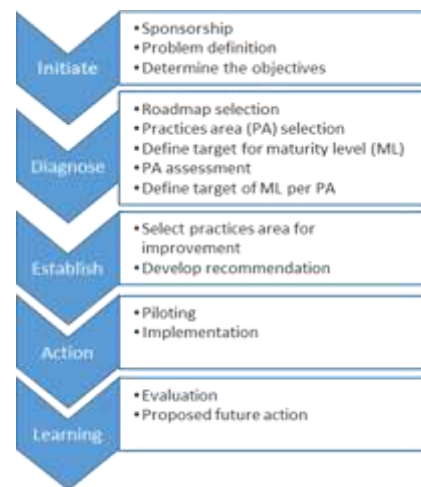


Figure 1. Research Step

cycle in this research.

a. Initiate phase: an analysis of the problems in the current software development process to recognize and understand the need to make improvements. Also, this phase determined the context and sponsorship for process improvement software programs.

b Diagnose phase: The process of determining the CMMI Roadmap will be carried out in this phase. After that, based on the CMMI roadmap that has been selected, then determine which practice area the assessment process will take. Before

the assessment is carried out, the maturity level target is needed first. Then an assessment process is carried out based on the selected practice area and the specified maturity level target. Finally, after obtaining the results of an assessment of the practice area, a process was carried out to determine the maturity level target per practice area.

c. Establish phase. To determine which practice area will be carried out by the improvement process based on the results of the diagnosis process. After getting the practice area that requires improvement, the recommendations are based on the instructions in CMMI Model Version 2.0.

d. Action phase. After making recommendations for improvement in the established phase, the next step is piloting the recommendations on several pilot projects. Then, recommendations for improvements will be applied to the entire project in the organization.

e. Learning phase. The next step is the evaluation and learning of the results of recommendations for improvements that have been implemented. The results of this stage will become an input into the next IDEAL process cycle.

### C. Sample and Data Collection Method

This research collects data to determine the organization's issues and objectives. This data is derived from the questionnaire (CMMI Roadmap questionnaire). This questionnaire is limited to workers in organizations involved in the software development process. This questionnaire was distributed to one manager and two assistant managers in 6 departments in the organization (the total number of respondents was 18). The CMMI Roadmap questionnaire aims to determine each roadmap's significance. The amount of significance for each roadmap is achieved by scoring each objective and problem on the CMMI roadmap. Scoring is performed by summing the values acquired from each respondent for each objective and problem in the CMMI roadmap. The summation outcomes are then calculated on averages for objectives and problems on the CMMI roadmap. The higher average score indicates that these objectives concern the organization on the CMMI roadmap for organizational objectives. While on the organizational problem roadmap of the CMMI, the higher the average score indicates how critical the issue is for the organization.

## IV. Result and Analysis

### A. Initiating

#### 1) Problem Statement

The main problem when developing software in the IT Division is that the product quality does not meet expectations. The problem can be seen from the many software not finished on schedule.

#### 2) Determine the Objective

The author will use the CMMI-Dev framework as a solution to these problems. This research will use the IDEAL framework for the research stage. Therefore, the purpose of

this research is to develop recommendations that can improve the quality of the software produced by the IT Division based on the application of CMMI-Dev

### B. Diagnosing

#### 1) CMMI roadmap selection

To determine the CMMI Roadmap that best fits the company's conditions, the authors create a table to match the problems and needs of the company with the roadmap. All indicators of objectives and problems are taken from the SEI report entitled CMMI Roadmap [5] (Cannegieter, Heijstek, Linder, & Solingen, 2008).

The organization's focus questionnaire aims to determine which objectives are the organization's focus in the software development process and to find out which present issues are the organization's focus. The organization's focus for each roadmap can be identified by scoring each objective and problem on the CMMI roadmap. Scoring is performed by summing the values acquired from each respondent for each objective and problem in the CMMI roadmap. The summation outcomes are then calculated on averages for objectives and problems on the CMMI roadmap.

Table 1 provides the objectives and problems to address by implementing the project roadmap [5]. The process area in this roadmap focuses on project management.

TABLE I. PROJECT ROADMAP - OBJECTIVE AND PROBLEM.

The objective that the roadmap wants to achieve	Code	Score	Weighted score	Avg weighted score	Final score	
The project meets its requirement	A-O-1	4.67	4.67		7.72	
The correctness of the time and effort estimation on the project	A-O-2	4.22	4.22			
Good Project planning	A-O-3	4.56	4.56			
Involvement of relevant stakeholders	A-O-4	4.56	4.56			
Monitoring and control of the project	A-O-5	4.33	4.33			
Problems that the roadmap wants to solve	Code	Score	Weighted score	Avg weighted score		
Poor project planning	A-P-1	3.22	3.22	3.26		
No clear scope and requirement for the project	A-P-2	3.33	3.33			
Limited involvement in relevant stakeholder	A-P-3	3.17	3.17			
Limited insight into the project progress	A-P-4	3.17	3.17			
Scope creep, budget overrun, and delayed completion	A-P-5	3.39	3.39			

Table 2 consists of the objectives to be achieved and the problems that want to be addressed by implementing the

product roadmap [5]. The primary purpose of the product roadmap is to improve the quality of the products produced.

TABLE II. PRODUCT ROADMAP - OBJECTIVE AND PROBLEM

The objective that the roadmap wants to achieve	Code	Score	Weighted score	Avg weighted score	Final score
Quality of the products	B-O-1	4.61	4.61	4.36	5.56
No problems with products after release	B-O-2	4.28	4.28		
Efficient development time	B-O-3	4.00	4.00		
Customer satisfaction	B-O-4	4.56	4.56		
Problems that the roadmap wants to solve	Code	Score	Weighted score	Avg weighted score	
Dissatisfied Customer	B-P-1	2.61	2.61	1.20	
Too many defects in the delivered product.	B-P-2	2.94	0.00		
High maintenance cost	B-P-3	2.61	0.00		
Difficulties in finding defects in the earlier project lifecycle	B-P-4	3.39	3.39		
Insufficient control over product quality	B-P-5	3.44	0.00		

Table 3 presents the objectives to be achieved and the problems that want to be addressed by implementing the product integration roadmap [5]. The process area in this roadmap focuses on product integration during development and deployment.

TABLE III. PRODUCT INTEGRATION ROADMAP - OBJECTIVE AND PROBLEM

The objective that the roadmap wants to achieve	Code	Score	Weighted score	Avg weighted score	Final score
Gain control over the integration process	C-O-1	4.33	4.33	3.47	5.50
High confidence in product compatibility	C-O-2	4.22	4.22		
Quality overall system (after product integration)	C-O-3	4.50	4.50		
Products fit the market needs	C-O-4	4.28	4.28		
Well-qualified suppliers	C-O-5	4.28	0.00		
Problems that the roadmap wants to solve	Code	Score	Weighted score	Avg weighted score	
Bad coordination between various parties in the project	C-P-1	3.33	0.00	2.04	
No Control over the	C-P-2	3.17	3.17		

integration process				
No Insight into whether the product meets customer needs	C-P-3	2.94	2.94	

Table 4 describes the objectives to be achieved and the problems that want to be addressed by implementing the process roadmap [5]. The process area in this roadmap focuses on improving the standardization of processes in the organization and ensuring that every process runs according to these standards.

TABLE IV. PROCESS ROADMAP - OBJECTIVES AND PROBLEM.

The objective that the roadmap wants to achieve	Code	Score	Weighted score	Avg weighted score	Final score
Ability to define and analyze current processes	D-O-1	4.33	0.00	2.09	2.62
Accurate process improvement	D-O-2	3.94	0.00		
Standardize the processes of the organization	D-O-3	4.06	4.06		
Continuous process improvement	D-O-4	4.33	0.00		
A clear standard of quality	D-O-5	4.17	4.17		
Processes that are compliant with applicable regulation	D-O-6	4.33	4.33		
Problems that the roadmap wants to solve	Code	Score	Weighted score	Avg weighted score	
A lack of clear understanding of the project process	D-P-1	2.83	0.00	0.53	
A lack of control over a particular process	D-P-2	3.11	0.00		
Difficulties during handover	D-P-3	3.72	3.72		
Limited adoption of a defined process	D-P-4	3.17	0.00		
Employees do not collaborate well in the company	D-P-5	2.67	0.00		
Limited ability to identify the problem	D-P-6	2.61	0.00		
Difficulties in improving the process	D-P-7	3.22	0.00		

Table 5 shows the objectives to be achieved and the problems that want to be addressed by implementing the measurement roadmap [5]. The process area in this roadmap focuses on improving the standardization of processes in the organization and ensuring that every process runs according to these standards.

## 2) CMMI practice area selection

Based on the problems faced and the company's objectives, the project roadmap is the most suitable roadmap

to implement for Bank XYZ. The project roadmap has five process areas in CMMI version 1.3: project planning, project monitoring and control, requirements management, configuration management, and process and product quality assurance.

TABLE V. MEASUREMENT ROADMAP - OBJECTIVES AND PROBLEM.

The objective that the roadmap wants to achieve	Code	Score	Weighted score	Avg weighted score	Final score
Ability to measure performance improvements quantitative	E-O-1	3.94	3.94	2.07	3.25
Ability to determine which improvement to be done based on quantitative data	E-O-2	4.33	0.00		
Be able to demonstrate the result of process improvement quantitatively	E-O-3	3.94	0.00		
Be able to determine the most critical KPI for the organization	E-O-4	4.33	4.33		
Problems that the roadmap wants to solve	Code	Score	Weighted score	Avg weighted score	
A lack of quantitative information to understand	E-P-1	3.28	3.28	1.18	
Identifying and selecting improvement activities without adequate information	E-P-2	3.28	0.00		
A sceptical management team to the improvement of the organization	E-P-3	2.61	2.61		
A need to use quantitative information to show the added value	E-P-4	3.39	0.00		
Excessive measurement system error	E-P-5	3.33	0.00		

To use this roadmap in CMMI version 2.0, mapping the existing CMMI version 1.3 process area with the CMMI version 2.0 practice area. Table 6 shows a mapping between the process area in CMMI version 1.3 with a practice area in CMMI version 2.0 for the project roadmap.

TABLE VI. THE MAPPING BETWEEN PROCESS AREA CMMI V1.3 AND PRACTICE AREA CMMI V2.0

CMMI V 1.3	CMMI V 2.0
Project Planning	Planning (PLAN)
	Estimating (EST)
Project Monitoring & Control	Monitoring and Control (MC)
	Risk and Opportunity Management (RSK)
Requirement Management	Requirement Development Management (RDM)
Configuration Management	Configuration Management (CM)
Process & Product Quality	Process Quality Assurance (PQA)

Assurance
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### 3) Target capability level for assessment

To improve the quality of products, Bank XYZ needs to improve the condition of the current software development process. Currently, the IT Division maturity level in the practice area that aligns with the roadmap project is unknown. Therefore, an initial target of maturity level is needed to start the assessment. For example, an organization should target level 3 maturity levels [10]. By implementing maturity level 3, the company will get a lot of added value, such as improving project management, risk management, validation and verification, and several others.

### 4) CMMI assessment

The assessment of practice area planning aims to find out how the Bank XYZ company develops a plan to describe what is needed to complete the work in the standards and constraints of the organization, including the budget, schedule, demand for resources, capacity, quality, functional requirements, risk, and opportunity. The assessment results were obtained from a questionnaire given to 3 respondents (a manager and two assistant managers) whose work was related to planning activities.

- a. **Planning (PLAN).** The final score is obtained by performing the floor operation at the average value of each practice statement. All practice in maturity level 1 is categorized as satisfied, four practices from 8 practices in maturity level 2 are categorized as satisfied, and one practice in maturity level 3 is categorized as satisfied.
- b. **Estimation (EST).** All practice in maturity level 1 is categorized as satisfied. However, all practices in maturity levels 2 and 3 are categorized as unsatisfactory. Therefore, it can be concluded that the IT division is still at a maturity level 1 for practice area estimation
- c. **Monitoring and Control (MC).** All practice in maturity level 1 is categorized as satisfied. Only one practice from 4 practices in maturity level 2 is categorized as satisfied, and all the practice in maturity level 3 is categorized as not satisfied.
- d. **Risk and Opportunity Management (RSK).** All practice in maturity level 1 is categorized as satisfied. In maturity level 2 and level 3, all the practice is categorized as unsatisfactory.
- e. **Requirement Development Management (RDM).** All practice in maturity level 1 is categorized as satisfied. Only one practice in maturity level 2 is categorized as not satisfied. 4 out of 7 practices are categorized as satisfied for maturity stage 3.
- f. **Configuration Management (CM).** All practice in maturity level 1 is categorized as satisfied. Only one practice in maturity level 2 is categorized as satisfied.
- g. **Process Quality Assurance (PQA).** All practice in maturity level 1 is categorized as satisfied. Only one practice in maturity level 2 is categorized as satisfied.

As a result, all practice areas on the project roadmap at capability level 1 are fully implemented. This means that the IT division of Bank XYZ has implemented all practices in the PLAN practice area, EST, MC, SSR, RDM, CM, and PQA for capability level 1 and there is no need for improvement. On the other hand, Bank XYZ still does not meet capability level 2 and 3. This can be seen from not all the practice areas reaching 100% implementation. Therefore, there is an opportunity to improve the process in practice that is still not fully implemented.

### 5) Target capability level for each practice area

To achieve maturity level three, companies must implement all practices on maturity level two. However, Bank XYZ still has not implemented the overall practice area on the project roadmap for maturity level two. Therefore, the target level addressed is maturity level two, as shown in Fig. 2.

Practice Area	Capability Level 1	Capability Level 2	Capability Level 3
PLAN	100%	50%	25%
EST	100%	67%	0%
MC	100%	25%	0%
RSK	100%	0%	0%
RDM	100%	83%	57%
CM	100%	17%	0%
PQA	100%	25%	0%

Figure 2. Comparison of Capability Level

### C. Establishing

After the assessment results of the fulfilment of the practice statement are obtained, the next step is to identify any practice areas that need improvement. Based on the assessment results, each practice area on the project roadmap has been classified into satisfied and unsatisfied. The practice categorized as satisfied is a practice with fulfilment values fully implemented and primarily implemented. Whereas a practice classified as not satisfied is a practice that has partially implemented and not implemented fulfilment values [11]. Furthermore, the target maturity level for each practice area is another item that needs to consider. It is discovered that each practice area has a target maturity of level 2, depending on Fig. 2. So any practice categorized as unsatisfied and at maturity level 2 will be improved.

The recommendation which is suitable for the IT division of Bank XYZ consists of four recommendations for Planning (PLAN) practices, one for Estimating (EST) practices, three for Monitoring and Control (MC) practices, two for Risk and Opportunity Management (RSK) practices, one for Requirement Development Management (RDM) practices, five for Configuration Management (CM) practices, and three process Quality Assurance (PQA) practices. An example of recommendation for PLAN and EST can be seen in Table 7 below. All recommendation is based on practice on CMMI 2.0.

After the recommendations are carried out on the entire software project, the next step is evaluating the results of recommendations for improvements that have been implemented.

TABLE VII. THE EXAMPLE OF THE CURRENT CONDITION OF THE SELECTED PRACTICES AND RECOMMENDATIONS

Code	Planning (plan)		
	Practice Statement	Current condition	Recommendation
[PLA N] 2.1	Plan transition to operations and support.	There is no plan for a transition to operations and support	Use is System Integration Test (SIT) document and Standard Operational Procedure (SOP) by determining transition scope, transition criteria and requirements, approach to transition; developing a schedule for transition, determining transition resource; determining operation and support training
[PLA N] 2.2	Ensure plans are feasible by reconciling available and estimated resources.	It is rarely done to reconcile the estimated resources.	<ol style="list-style-type: none"> <li>Perform resource levelling by adjusting the scheduling of tasks, balancing the demand for a resource with their availability, modifying or deferring requirements, negotiating more resources, finding ways to increase productivity, outsourcing, modifying the scope, and others.</li> <li>Ensure commitment. Make sure adequate personnel or other required resource supports the commitments.</li> <li>Negotiate commitment and coordinate work timing expectations, and result with the affected stakeholder.</li> <li>Revised Plan and Commitment, make sure every change is recorded on the Revised Plan and Commitment</li> </ol>
[PLA N] 2.3	Develop the project plan, ensure consistency among its elements, and keep it updated.	[PLAN] 2.6 is not satisfied, so it is hard to ensure consistency, and not all projects develop a complete project plan.	<ol style="list-style-type: none"> <li>Record the project plans. The plan generated for the project defines all aspects of the effort, tying together the following in a logical manner: task, budget and schedule, milestones, information management and governance, risk, resource and skills, stakeholder roles and involvement, infrastructure, and others.</li> <li>Review the project plan with affected stakeholders. Ensure that the project plan describes a realistic approach for meeting the needs, expectations, and constrain of affected stakeholders and help ensure that these affected stakeholders will fulfil their roles.</li> <li>Revise the plan as necessary because planning is an iterative activity.</li> </ol>
Code	Estimation (est)		
	Practice Statement	Current condition	Recommendation
[EST] 2.1	Based on sized estimates, develop and record effort, duration, and cost estimates and their rationale for the solutions.	Estimates are sometimes made contrary to the wishes of the manager, so estimates based on the wishes of the manager made not	<ol style="list-style-type: none"> <li>Collect historical data to transform size estimates into effort duration and cost. To ensure high-level confidence in estimate, use multiple models or methods as needed</li> <li>Describe and record the rationale for estimating the solution's effort, duration, and cost. Recording the rationale provides the context using historical data for estimating future work.</li> </ol>

Code	Planning (plan)		
	Practice Statement	Current condition	Recommendation
		based on a rationale	3. Include an estimate of supporting infrastructure needs. The supporting infrastructure includes resources needed to support the project but is not necessarily included in the project.

Evaluation is carried out to determine whether the recommendations can be carried out correctly, whether there are factors that hinder the course of recommendations, which drive successful implementation, whether the recommendations are positive or negative and other factors. Evaluation is done by gathering all relevant stakeholders so that the evaluation results will cover all stakeholder needs.

## v. Conclusion and Future Work

Based on the assessed values of the CMMI roadmap, the most significant organizational problems are project management, product development and product integration. According to these outcomes, it can be concluded that the project roadmap is the most suitable for implementation by the organization. This is because the objectives of the project roadmap are most in line with the focus of the current organizational objectives and are most appropriate for addressing current problems in the organization. However, several areas of the software development process at Bank XYZ need to improve – planning, requirement development, estimation, quality assurance, configuration management, monitoring and control, and risk and opportunity management. Therefore, this study proposes several structured recommendations for handling the improvement process in those areas.

This study comes with some limitations and provides future research directions. This study is based on continuous representation, which employs the CMMI roadmap to select the practice area for improvement. The result does not reflect the organization's overall condition or performance. The staged representation can be used to improve the overall performance of the organization's software process. Using a questionnaire for data collection, the assessment value of some practice statements may be ignored. Interviews and observations can therefore be utilized to improve the data quality in future research. To validate and improve the proposal, it may be prudent to validate it in a wide range of organizations that may provide a variety of conditions, including different processes, company size, and more experts. This study uses SCAMPI C as its evaluation approach. By doing SCAMPI A or SCAMPI B appraisal, the evaluation of maturity and capability can be enhanced.

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