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Evaluating The Influence Of Some Factors On Capability Maturity Model Integration For Development (Cmmi-dev) Maturity Level

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EVALUATING THE INFLUENCE OF SOME FACTORS ON CAPABILITY MATURITY MODEL INTEGRATION FOR DEVELOPMENT (CMMI-DEV) MATURITY LEVEL

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by

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ABSTRACT

Capability Maturity Model Integration for Development (CMMI-DEV) is a collection of characteristics of effective processes that guide improving an organization's operations and ability to manage software projects' development. The CMMI-DEV maturity levels range from 1 to 5 for the staged model; however, there are no certifications for maturity level 1. Organizations appraised may seek higher CMMI-DEV maturity levels. Most clients will seek to do business with organizations with at least CMMI Maturity Level 3 certification.

This research aimed to find if software development methodology (SDM), CMMI training, and other process improvement (OPI) standards affect CMMI maturity level rating. The dependent variable (maturity level rating) was ordinal, and the three independent variables were nominal with categories. Ordinal regression was used for hypothesis testing and data analysis. Data was collected using a web-based questionnaire from participants across the globe from organizations engaged in software development and with a current maturity rating in the CMMI Institute online database. The response rate was low as there were only 119 participants with only 109 valid responses. The researcher used descriptive statistics to describe the sample for this research. The data was processed using SPSS for ordinal regression. The results revealed that there was no statistical significance of SDM and OPI on the CMMI maturity level rating. However, the CMMI training was found to have a significant effect on the CMMI maturity level. The CMMI training – training without certification was found to be statistically significant in predicting the next

CMMI maturity level on the sample used.

The study can be used to investigate factors for the other CMMI constellations, i.e., services and acquisitions. The results from this study cannot be generalized but can be used in conclusions related to this study.

This research yielded various unexpected results due to a low participation or response rate. There were 119 responses from the more than 400 selected participants and only 109 valid responses for this research.

CMMI is still relevant in today's software development world; however, these SDOs should allow access to researchers to explore the factors that can benefit SDOs and add to their bottom line.

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DEDICATION

This dissertation is dedicated to my parents, Isaka Nyaberi Bw'Ogega and Agnes Nyanduko Ogega – the Greatest of All Time. The people behind my pursuit of education and everything life has to offer. The folks who made me believe that "knowledge for knowledge's sake will set you free." I promise that I will keep seeking knowledge until I am free. THANK YOU!

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CHAPTER 1

INTRODUCTION

Overview

Software engineering and development have improved software products in the last few years. Many of the world's appliances have memory chips embedded in the machines. These chips are loaded with algorithms or software that enable functional use in an automated fashion. For example, smart devices in the home can regulate the home environment temperature, record activities in the house, and send updates to a smart or lock and unlock homes. Software advances have made it possible to move from traditional filing and record-keeping to cloud-based storage.

Software engineering and software development will be used interchangeably throughout this research for simplicity. Software development has undergone rapid changes, just like any other technological sector. Over the past few years, technology has made many substantial advances and improvements and suffered catastrophic failures and setbacks. Some of these significant failures have captured headline news and made history, like the Mars Climate Orbiter, the millennium bug, and the severe software glitch in the F-35 Joint Strike Fighter (JSF) (Osborn, 2015) and the most recent T-Mobile data breach in 2021. Data breaches have become very common worldwide, and companies are working with Information Technology (IT) Subject Matter Experts (SMEs) to prevent unauthorized access to data by software programs. A bug-free product is an ideal goal for any software developer. However, to get there, Software

Development Organizations (SDOs) must engage in processes with clear objectives and foundations to eliminate software bugs and ensure flawless system integration. As software development emerged, many SDOs started to develop best practices that have continued to help them deliver quality software products to their customers.

There have been other best practices that have been widely used in the software industry since the 1980s. Two of these best practices were Total Quality Management (TQM) and International Organization for Standardization (ISO) 9000 because of their clear and concise quality objectives and how to achieve them for new products. (Liou, 2011). Many of these practices have morphed into different software process improvement standards, such as CMMI, the International Organization for Standardization (ISO) series, Control Objectives for Information and Related Technology (COBIT), and the American Society for Quality (ASQ) Software Division.

SDOs have given greater importance to gauging their competency or maturity through CMMI. CMMI is a performance improvement model for competitive organizations that want to achieve high-performance operations. CMMI provides a set of practices for improving processes, resulting in a performance improvement system that paves the way for better operations and performance (Carnegie Mellon University, 2016). Many organizations have taken the time to find value in measuring their capabilities and performances through CMMI appraisals. A CMMI appraisal is an activity that helps an organization identify the strengths and weaknesses in their processes and how closely their business processes relate to CMMI best practices.

CMMI appraisal activities can help an organization adopt the most efficient and effective improvement results in their CMMI journey. The appraisal can help an organization do various things, including an improvement plan, mitigating product development risks, and increasing customer confidence in product quality. CMMI maturity level rating is a source of competitive advantage. (Hayes, Lu, & Rezania, 2022)

CMMI maturity level appraisal has become the differentiator in SDOs part of the contract bidding process and attracting new business.

The CMMI History

CMMI is the successor of the Software Capability Maturity Model (SW-CMM) developed in the 1980s by the Carnegie Mellon Software Engineering Institute (SEI). The Capability Maturity Model Integration (CMMI) was an expert program designed by Carnegie Mellon University to guide training and appraisal processes in projects, organizations, and departments. The Carnegie Center was sponsored by the United States Department of Defense (DoD). Discovered in 1987, the software framework tool was initially published in 1991 with a list of success elements for software development projects. The Capability Maturity Model of 1987 lasted until 1997, after which different versions were developed. *Figure 1* below shows the history and branching of CMMs up to v1.3. The current CMMI version 2.0 and the model incorporate Practices from the three V1.3 constellations (DEV, ACQ, and SVC) plus the People CMM, as depicted in *Figure 2* below. (Multi-Dimensional Maturity, 2021). An observation can be made from history that there is a need for best practice frameworks that can act as the basis for reliable and consistent appraisals and effective process improvement programs (Paulk, 2009).

CMMI for Development (CMMI-DEV) has well-defined and easy-to-grasp processes. They comprise standards and procedures and methods and tools for effective organizational strategies. The CMMI models use a multidimensional approach and have been tested by experts to ensure reliable and cost-effective operations (Richardo, Sanjay, & Luis, 2014)

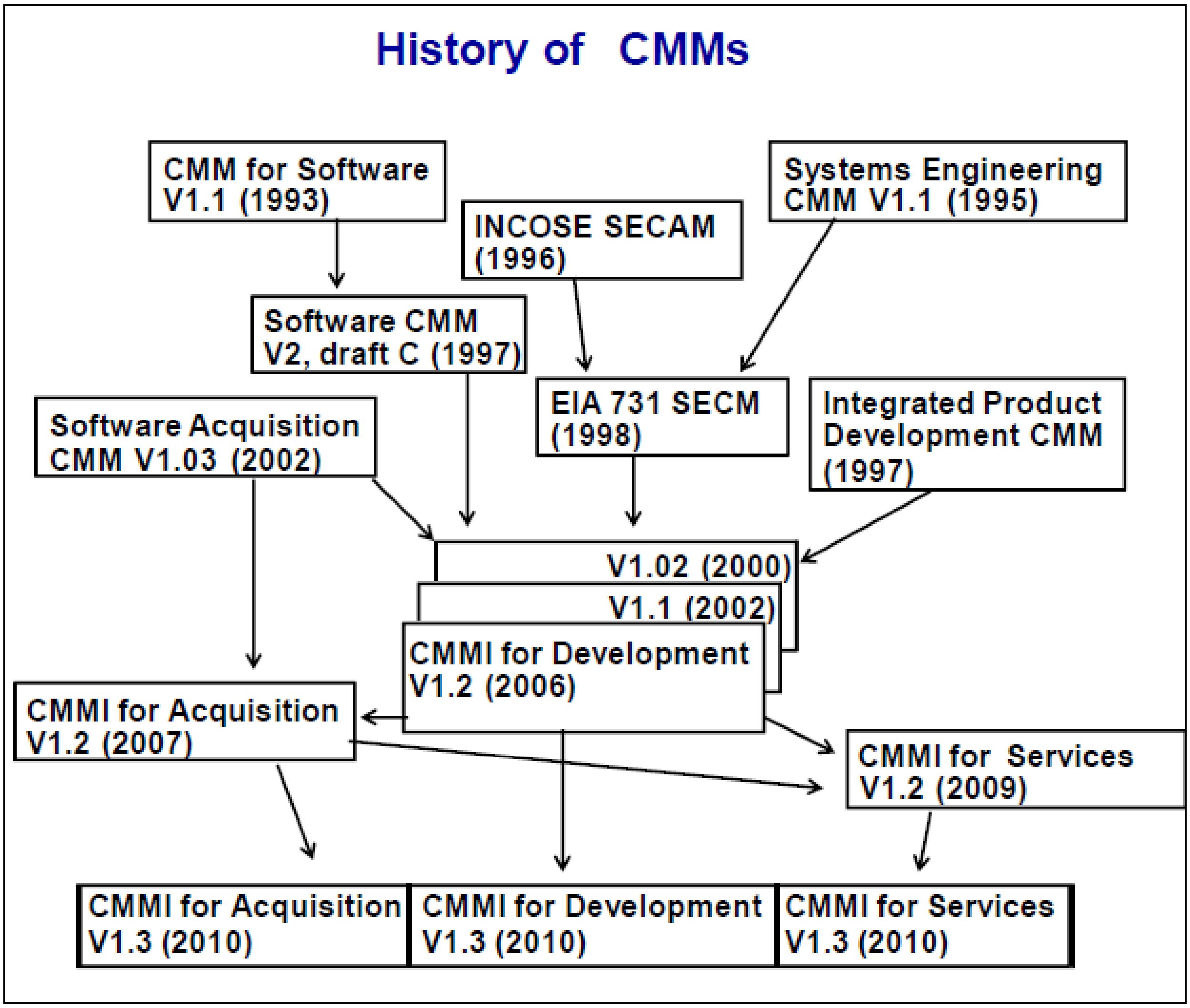

Figure 1. The history of CMMs (Carnegie Mellon, 2010)

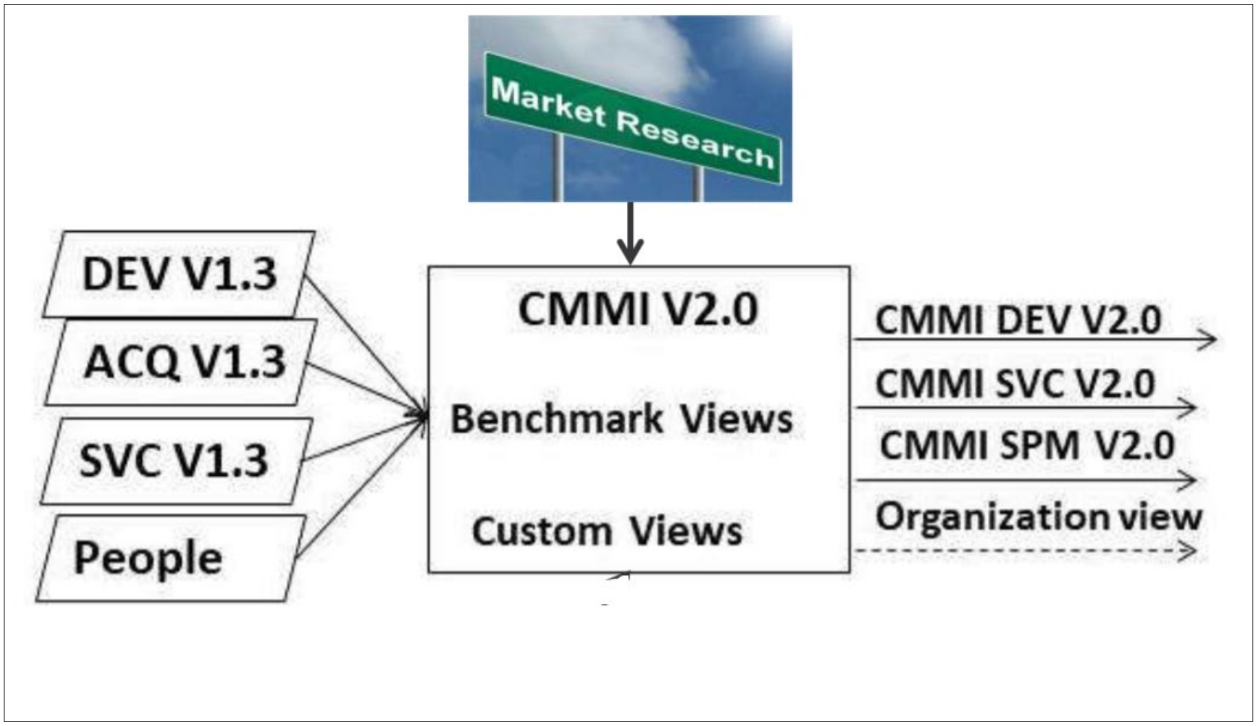

Figure 2. Current CMMI v2.0 (Multi-Dimensional Maturity, 2021).

The Model

The CMMI model is a top-down model with five levels, developed from the Crosby Manufacturing Maturity Model (Paulk, 2009)**.** Unlike its brainchild, the CMMI was revised throughout, compatible with various industries, and has become a focus in the last two decades. It is a reference model covering activities for developing both products and services. The model has two representations, staged and continuous, as seen in *Figure 3* below. These representations allow an organization to zero in and focus on different improvement objectives. In the continuous representation, there are six capability levels numbered 0 to 5. These six capability levels correspond to a generic goal and set of general or generic and specific practices and, therefore, focuses on individual process areas. In the staged representation, the model components are called maturity levels, numbered from 1 to 5. The maturity levels apply to the organization's overall maturity, and an external independent auditing team conducts the assessment.

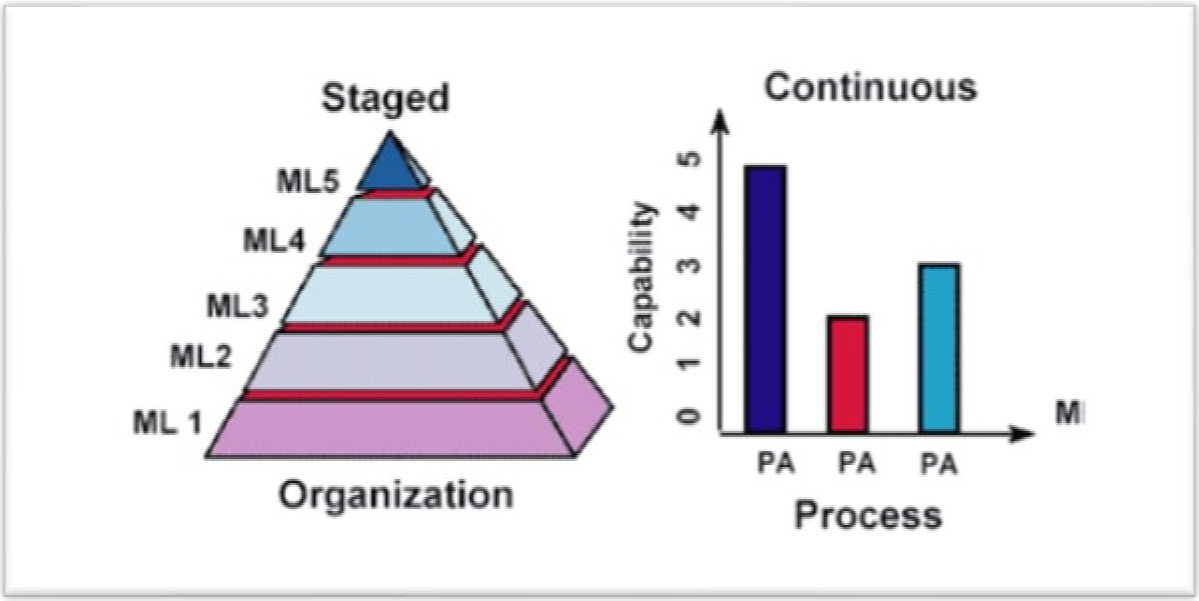

Figure 3. Staged and continuous models' representation (Tarnowski, 2014)

The CMMI continuous representation model is a general collection of best practices that cover basic concepts fundamental to process improvement in any area of interest in an organization. The fundamentals of CMMI are applications of small, incremental changes in processes to improve efficiency and quality and cut costs. CMMI's tenets are rooted in process improvements that have a progressive maturation that resides in the cumulative capability levels. The capability level is a continuous representation of an organization's capability in any process areas.

The CMMI staged representation model focuses on the overall maturity and state of an organization's improvement achievement across multiple process areas (Chrissis, Konrad, & Shrum, 2011). Each maturity level is the building block of the next maturity level. The maturity level is an assessment carried out by an independent external team using an official CMMI appraisal method. The maturity level is awarded based on the results of the appraisal activity.

The CMMI-DEV model specifies that a project or an organization should have processes that address development-related practices (Carnegie Mellon, 2010). It is a set of guidelines for organizations' integration process and product improvement procedure**.** The CMMI-DEV model focuses on the structure of the process that holds everything together (Cestari J. P., Maria do Valle, Pinheiro de Lima, & Santos, 2013).

CMMI started as one model that combined three source models into a single improvement framework to pursue enterprise-wide process improvement. These models were: *Capability Maturity Model for Software* (SW-CMM) - v2.0 Draft C, *Systems Engineering Capability Model* (SECM) [IEA 2002a], and the *Integrated Product Development Capability Maturity Model* (IPD-CMM) v0.98 (Carnegie Mellon, 2010). Today CMMI offers three components that are called constellations. These constellations are CMMI for Acquisition (CMM-ACQ), CMMI for Development (CMMI-DEV), and CMMI for Services (CMMI-SVC). The focus of this research was on the CMMI-DEV constellation.

The CMMI-DEV constellation provides a collection of best practices that cover developing products and services. These activities are structured around applying the applied capability maturity model for organizations and a set of appraisal methods and training courses that accompany the model. CMMI-DEV model aims to provide best practices for organizations determined to remove inefficiencies from their software product development capabilities. These best practices contained within the model apply to the development of products that have one or more of the following elements—hardware, software, firmware, or people (Carnegie Mellon University, 2009)

The CMMI-DEV has become a popular Software Process Improvement (SPI) model for enhancing software development processes to develop high-quality software products within budget, which meets customer's schedules (Alyahya, Ahmad, & Lee, 2012). Software companies passionately compete in a highly competitive environment to offer quality software products and services that exceed customers' expectations. These products must be user-friendly but highly sophisticated to provide information protection against cybersecurity threats and vulnerabilities. Software development organizations have renewed and greater focus on achieving capability levels in their processes to obtain organizational maturity (Galvis-Lista & Sánchez-Torres, 2013).

CMMI models guide the developing and improving processes that meet organizational business goals. Today, the CMMI Institute is part of the Information Systems Audit and Control Association (ISACA). Initially, CMMI was used by the US Department of Defense and the US government agencies. Today, CMMI is featured as a processes improvement model for a software development application for the business environment across different industries because of its ability to deliver quality software products. (Laporte et al.,.2013)

The model has two representations, staged and continuous, as shown in Figure 2. These representations allow an organization to zero in and focus on different improvement objectives. This research focused on the staged representation of the CMMI-DEV model.

The staged representation CMMI model ranks organizations from CMMI level 1 to CMMI level 5 for software development. A maturity level is a spick-and-span progression toward achieving a mature software process. Maturity levels consist of a prescribed set of process areas that meet the maturity level's specific and generic goals. The next level is built upon the previous level, and meeting other goals to advance to the next level is significant to continuous process improvement. Following are the five maturity levels that an organization can be ranked.

1. Initial
2. Managed
3. Defined
4. Quantitatively Managed
5. Optimizing

The CMMI model is typically aligned with the organization's business objectives and goals. At the very minimum, the process-improvement concept in CMMI models should include producing quality products and services while creating value for stockholders and enhancing customer satisfaction.

An organization's leadership must have CMMI involvement through management commitment to improve successful implementation chances. They need to encourage staff participation and provide the required CMMI training that includes an implementation plan that is well documented. Many organizations that have successfully had a CMMI level 3 or higher have the right processes. The organizations that have applied the model effectively have an accompanying commitment to various organizational cultural elements such as leadership, a compelling vision or mission, and shared values (Millar, 2014). There is no appraisal for maturity level 1. Formal appraisal starts at maturity level 2.

Factors That Affect CMMI Maturity Level

For process improvement initiatives to qualify as successful, they must focus on the organization's business objectives. Critical factors for a software development organization are delivering the product/project on time and within budget while maintaining high quality and fulfilling the customer's functional and non-functional requirements. CMMI categorizes the process areas into four major categories to ensure that all of these critical factors are addressed in one way or another. Process Management, Project Management, Engineering, and Support are the four major categories. These four categories have twenty-two process areas in total (Majumdar, Ashiqe-Ur-Rouf, Islam, & Arefeen, 2011).

The CMMI model describes the best practices organizations have found to be productive and valuable to achieving their business objectives. Regardless of an organizational structure and process improvement framework, one must use professional judgment when interpreting CMMI best practices for each situation, needs, and business objectives (Carnegie Mellon, 2010). The five maturity levels have a cluster of related practices in process areas. These process areas have been categorized for each maturity level.

Some factors can affect the outcome of a CMMI appraisal activity on an organization considering a maturity level rating. Among these factors are poor quality of software products and processes (Walia & Carver, 2009); software methodology development practices like agile (Bass, Allison, & Banerjee, 2013), organizational training (Galvis-Lista & Sánchez-Torres, 2013), include CMMI training, and other software improvement standards (Laporte & O'Connor, 2017).

Software Development Methodologies

The use of software development processes has been in existence for decades. These development processes have evolved into models or methodologies (Fuggetta, 2000). A software development methodology is a framework to structure, plan, and control software development (Association of Modern Technologies Professionals, 2018). Two software development methodologies are primarily agile and waterfall or traditional software development life cycle. Other methods are not commonly used.

A recent study on software methodologies in the United States showed that 47% of the respondents described their software methodology as agile, 24% as scrum, 23% as waterfall, and 5% as other (Paul, 2020). Scrum is an agile development framework, so agile and scrum will be grouped in this research.

Agile Software Development Life Cycle

Agile software development emerged in the early 2000s. Agile software development life cycle is an iterative way of software development. Each iteration lasts two to four weeks with a fixed completion time (Step-by-Step Guide to Agile Software Development Life Cycle, 2019).

This specified period is called a sprint. A functional piece of software is expected at the end of each sprint.

Waterfall Software Development life Cycle

Waterfall or traditional software development life cycle is a linear process that follows a sequential software development that starts with requirements and ends with software delivery. The waterfall is less flexible and takes a long time to deliver working software.

The Waterfall method is very contract-oriented. An agreement between the customer and the development team on the requirements and project scope must be signed before development occurs. Any changes to requirements or scope should be made through a Change Control Board (CCB) in long and linear iterations. The waterfall lifecycle is characterized by a sequence of stages in which each stage's output becomes the input for the next.

There is a linear relationship between each phase of the development life cycle. (Balaji & Murugaiyan, 2012)

CMMI Training

CMMI training can be formal training or informal training. There are several online resources, including eLearning and Professional CMMI Training courses. These types of training are approved or recognized by SEI. Usually, an organization would provide CMMI training for anyone essential and involved in process improvement. To be part of an appraisal team, one needs to have completed the required CMMI training.

Other Process Improvement Standards

Software development is a complicated endeavor with high rewards when certain practices are followed. Software development relies on repeatability and reuse for high-end quality products and process improvement. There have been several standards other than CMMI to capture some of these practices that attempt to standardize them. Some of these standards have their beginnings in other industries, such as the ASQ in manufacturing. Some organizations have attempted to tailor CMMI to include some of the organization's earlier standards.

CMMI Maturity Level

Organizations or projects combining agile methods with CMMI have produced high-quality software that effectively exceeds customer requirements (Sutherland, Jakobsen, & Johnson, 2007). There are some challenges that some organizations have faced attempting to implement Agile into CMMI level 3 due to processes or customers not approving these processes. Sutherland et al. (2007) indicated that companies in the defense, aerospace, and other industries that required high CMMI maturity levels were not ready to introduce agile practices.

Process improvement methods have been used to help organizations conduct self-assessments covering various aspects of their quality objectives. ISO 9000 series is one such self-assessment scheme, specifically the ISO 9004:2000. The requirements for ISO 9004:2000 are mainly for the continuous improvement of an organization's overall performance and efficiency, as well as its effectiveness (Hwang, Kim, & Jeong, 2012)., maturity level mapping, breaks down the factors selected for this research and how they relate to the maturity level or the process areas. There is no factor mapping for maturity level 1. CMMI Maturity Level 1 is typically an unstable environment where an organization is highly reactive and do not have defined processes that can be used to repeat past success or lesson learned to avoid past failures. CMMI Maturity level 2 means that an organization has achieved all the specific and generic goals of the maturity level 2 process areas and can request a level 2 appraisal. An organization that requests a CMMI Maturity Level 3 can show that it has met the specific and generic goals for Level 2 and well-defined processes. At maturity level 3, processes are well characterized, understood, documented, and described in standards, procedures, tools, and methods. Quantitatively managing processes is the focus for CMMI Maturity level 4. At maturity level 4, an organization has achieved all the specific goals of the process areas assigned to maturity levels two and three, and detailed measures of process performance are collected and statistically analyzed to identify causes of process variation and work to predict and control the contributing factors. The final CMMI Maturity level is level 5. This level is considered the optimum maturity level. This level is concerned with addressing common causes of process variation and changing the process to improve performance. Few organizations pursue level 5 rating.

Table 1 Factor maturity level mapping

Factor	**CMMI Category**	**Maturity Level**
Software Development Methodology	Requirements Management (REQM) Project Planning (PP) Project Monitoring and Control (PMC) Management (SAM) Measurement and Analysis (MA) Process and Product Quality Assurance (PPQA) Organizational Innovation and Deployment	ML 2, ML3, ML4, ML5
Training	Integrated Project Management (IPM) Organizational Training (OT)	ML 3, ML4
Process Improvement Standards	Organizational Process Definition (OPD) Organizational Process Focus (OPF)	ML 3, ML4

Statement of Purpose

The CMMI Institute recently published the "Guide to Scrum and CMMI: Improving Agile Performance with CMMI®. This document's publication coincides with the release of the combined CMMI v2.0, which now includes direct guidance on enhancing agile development implementation.

This research explored the relationship between CMMI level rating and the factors of software development methodology, CMMI training, and process improvement standards. SDOs are under constant pressure to demonstrate successful past performance in their products and services sustainment and development. CMMI-DEV has presented the solution for tracking past projects' success in a competitive market for software developing companies. Measurement processes such as CMMI have provided organizations with a framework and enabled them to establish and institutionalize a set of measurements for software development processes (Pedroso & Oliveira, 2013). There are over 500k software companies around the world. Only about 1% participate in the CMMI maturity level rating. The study of the effects of software development methodology, CMMI training, and process improvement standards on CMMI-DEV maturity level rating provided insight into how these factors affect the CMMI maturity level rating.

Problem Statement

Today, CMMI is heavily used in the aerospace and defense industries in companies such as Raytheon, Boeing, Lockheed, and Northrup Grumman. Dalton et al. concluded that 90% of the CMMI adoption is outside the defense industry. Commercial sectors in IT firms like

Honeywell, Samsung, and Ericsson are spawning the foundation of a new process to integrate agile and CMMI in the workplace.

CMMI-DEV is a reference model aligned with necessary activities for developing both products and services in SDOs. These SDOs provide software solutions to aerospace, banking, computer hardware, software, defense, automobile manufacturing, and telecommunications (Carnegie Mellon, 2010). Many SDOs seek the CMMI level 3 or higher rating, even though high maturity levels have always been controversial when cost versus benefit takes center stage. Many organizations have adopted Maturity Level 3 as adequate and have chosen not to pursue high maturity levels (Campo, 2012). However, CMMI has not been applied as extensively in software development organizations (CMMI-DEV) as it has in acquisition (CMMI-ACQ) and services (CMMI-SVC). There is a need to understand CMMI's relationship and high product quality, timely and predictable deliveries that enable the best possible Return on Investment (ROI). Based on the literature review, a study evaluating the effects of software development methodology, CMMI training, and process improvement standards on CMMI maturity level rating does not exist. The results of the survey provided an understanding of the relationships between CMMI maturity level rating, software development methodology (SDM), CMMI training (CT), and other process improvements (OPI) standards for software development.

Research Question (RQ) and Hypotheses

RQ1: Does software development methodology (SDM) affect the CMMI maturity level?

Hypothesis 1: H_{01}: There is no difference in the CMMI maturity level whether the SDM is agile, waterfall, or other.

$\beta_{SDM} = 0$ {β is the regression coefficient, and SDM is the independent variable (IV), which can have three categorical values: agile, waterfall, or other.}

H_{A1}: There is a difference in the CMMI maturity level when SDM changes from agile to waterfall or other.

$\beta_{SDM} \neq 0$

RQ2: Does CMMI training affect the CMMI maturity level?

Hypothesis 2: H_{02}: There is no difference in the CMMI maturity level whether the CMMI training levels are no training, training with certification, and training without certification.

$\beta_{CT} = 0$ {CT: no training, training with certification, and training without certification}

H_{A2}: The CMMI maturity level changes when the CMMI training level changes from no training to training with certification or training without certification.

$\beta_{CT} \neq 0$

RQ3: Do other process improvement standards affect the CMMI maturity level?

Hypothesis 3: H_{03}: There is no difference in the CMMI maturity level regardless of the number of other process improvement standards adopted.

$\beta_{OPI} = 0$ {OPI: None, 1-2, 3 or more}

H_{A3}: There is a difference in the CMMI maturity level with at least one other process improvement standards are adopted.

$\beta_{OPI} \neq 0$

RQ4: Is there a two-way interaction in Software development methodology, CMMI training, and Other process improvement standards with regard to CMMI maturity level?

Hypothesis 4: H_{04}: There is no two-way interaction between Software development methodology, CMMI training, and other process improvement standards on CMMI maturity level.

$\beta_{OPI\_SDM} = \beta_{OPI\_CT} = \beta_{CT\_SDM} = 0$

H_{A4}: There is a two-way interaction between Software development methodology, CMMI training, and other process improvement standards on the CMMI maturity level.

At least one in (β_{OPI_SDM}, β_{OPI_CT}, β_{CT_SDM}) $\neq 0$

Statement of Assumptions

1. All the organizations considered for this study were software development organizations considering a CMMI maturity level rating appraisal.
2. The organizations were using the same software methodology across all projects.
3. Participants were software project managers or members of an appraisal team
4. Participants provided information to the best of their knowledge, and data were collected from organizations that had reported appraisal results by 2019. These organizations were randomly selected from the Information Systems Audit and Control Association (ISACA) portal (Published Appraisal Results, 2020).

Statement of Limitations

1. The study was for organizations engaged in software development, including the ones registered and who had active participation in the appraisal process, according to the current SEI report database.
2. There was a 20% participation rate from organizations contacted via the method approved by the IRB.
3. Findings are limited to the CMMI-DEV constellation.

Abbreviations

ASQ	American Society for Quality
CCB	Change Control Board
CMM-ACQ	CMMI for Acquisition
CMMI-DEV	Capability Maturity Model Integration for Development
CMMI-SVC	CMMI for Services
COBIT	Control Objectives for Information and Related Technology
CT	CMMI Training
DoD	Department of Defense
DSDM	Dynamic Systems Development Method
DV	Dependent Variable
FDD	Feature Driven Development
IPD-CMM	Integrated Product Development Capability Maturity Model
IPM	Integrated Project Management
IRB	Institution Review Board
ISACA	Information Systems Audit and Control Association
ISO	International Organization for Standardization
IV	Independent Variable
JSF	Joint Strike Fighter
ML	Maturity level
OPD	Organizational Process Definition
OPF	Organizational Process Focus
OPI	Other Process Improvement
OT	Organizational Training
PMC	Project Monitoring and Control
PP	Project Planning
PRINCE2	Projects IN Controlled Environments
REQM	Requirements Management
ROI	Return on Investment
SCAMPI	Standard CMMI Appraisal Method for Process Improvement
SDM	Software Development Methodology
SDOs	Software Development Organizations
SECM	Systems Engineering Capability Model
SEI	Software Engineering Institute
SPI	Software Process Improvement
SPICE	Software Process Improvement and Capability Determination
SPSS	Statistical Package for the Social Sciences
SW-CMM	Software Capability Maturity Model

TQM	Total Quality Management
XP	Extreme Programming

Summary

Research into determining the factors that influence CMMI maturity level rating is needed to lead organizations that desire to be appraised and intend to maintain the maturity level or move up to the next level. Dalton et al. argue that many organizations have not understood the factors influencing the CMMI maturity level rating.

Organization for the Remainder of the Study

This paper is organized as follows: Chapter 2 presents the literature's current state for the factors that affect CMMI maturity level rating. Chapter 3 is where the study's methodology and approach are discussed. Chapter 4 contains the detailed results for the findings, and Chapter five has the overall research implications and recommendations for further research.

CHAPTER 2

REVIEW OF LITERATURE

Overview

CMMI is not new to the software development industry. The software industry has adopted the CMMI-DEV model for process improvement. The model has been around for over three decades and has grown very slowly. Not many organizations have embraced and adopted the model for process improvement for their software development needs.

According to the SEI's latest report, organizations that have adopted the model have reported overall positive results (Published Appraisal Results, 2020).

It is possible to receive the CMMI training without the certification as a homegrown training. To obtain a certificate, one must train through an approved course through SEI or one of their approved partners. According to the *CMMI economics*, CMMI training can be costly (National Defense Industrial Association, 2017).

Defining the CMMI formal training and CMMI informal training variables for this research was challenging because not much work or study has been documented about this topic. However, quite a bit of research has been conducted on formal and informal training. The speed of technological advancements has forced many companies to be innovative and have encouraged their employees to be creative and flexibly adapt to new situations and tasks and develop the necessary competencies. Besides formal training, growing attention has therefore been devoted to informal learning at work, that is, all activities carried out to facilitate the accomplishment of one's work tasks (Messmann et al., 2018). The authors have described five formal and informal learning continua as shown in Figure 4. Individuals with formal CMMI training would fall under formal learning, and individuals with informal CMMI training would be categorized under informal learning. Individuals with formal CMMI training would be those with certified credentials or certificates from the responsible entity for offering such certificates (Messmann et al., 2018).

Messmann et al. (2018) theorize that there are potential benefits associated with informal learning, including better decision-making and innovative accomplishing tasks. The CMMI courses help participants connect the CMMI model and appraisal method with business value. The training will help participants understand what is involved in preparing for a CMMI appraisal.

The CMMI training with certification can become costly, especially if an organization must send several folks to this vendor-sponsored training. Many organizations will send a handful of people to complete the CMMI training with certification, bring them back, and have these individuals train others as a modified and home-grown version of CMMI.

Formal Learning	**Informal Learning**
High degree of structure	Low degree of structure
External validation	No external validation
Classroom setting	Workplace setting
Trainer-controlled	Learner-controlled
External stimulus	Internal stimulus

Figure 4 Formal and Informal Learning (Messmann et al., 2018)

Other Process Improvement Standards:

Organizational competitiveness, a demand in our global economy that has triggered economic and market globalization, has increased standardization demand (Aba et al., 2016).

Small software organizations use software process improvement (SPI) to reduce their development costs or increase their products' quality without causing delays to the development cycle (Espnosa-Curiel et al., 2016). Small software organizations tend not to invest resources in process improvement, and the ones that do typically do not have a tracking mechanism to self-assess. Espnosa-Curiel et al. (2016) found that many small organizations still struggle to successfully implement SPI initiatives due to a lack of knowledge and practical experience about the human, social, and organizational factors and their effects on SPI initiatives. Espnosa-Curiel et al. (2016) research supports changes in structure, culture, organizational climate, and projects to implement and sustain their SPI initiatives successfully.

Espnosa-Curiel et al. (2016) state that international organizations have proposed standards and SPI models to support SPI initiatives' implementation; examples are CMMI, ISO/IEC 15504 ISO/IEC 12207. These models describe a set of best practices and effective processes that serve as references for organizations to increase the maturity and capability of their processes. Many small software organizations do not adopt these models because they are too expensive or the ROI is not worth the effort. Espnosa-Curiel et al. (2016) found that 20% of small enterprises that participated in the CMMI appraisal evaluation between 2002 and 2010 maintained their process maturity certificates.

The CMMI-DEV model is for process improvement based on its business objectives. It focuses on the importance of structured processes to improve business performance and results.

Structured processes will enable an organization to align the way business is done for SPI. Furthermore, they allow an organization to address scalability and provide a way to incorporate knowledge of how to do things better. Processes will enable the organization to leverage resources, achieve process maturity, and provide an analysis of the current business trends (CMMI Product Team , 2018)

In recent years, many researchers have completed case studies explaining SPI initiatives' influence on various organizations. Some studies have shown that the overall organization's cultural values lead to a more structured and successful SPI initiatives implementation (Shih & Huang, 2010). Organizations management and other SPI agents are advised to reorganize the SPI initiative to accommodate better cultural variation within the organization (Müller et al. 2009)

There have been numerous changes to the software development methodologies in the software industry. The culture of an organization dictates the behavior and protocols of an organization. Changing an organization's culture is one of the challenges that leaders face today. Technology has experienced the most rapid change in the last few years. Software development has undergone even more changes in the methodologies that have helped SDOs cut costs and improve quality product delivery. Pushing these new methods through these SDOs has met cultural change challenges. Organizational culture is one factor that can influence the way professionals respond to SPI initiatives (Shih & Huang, 2010) (Müller et al., 2009) (Muller et al., 2008). Organizational culture can also explain an organization's success or failure in implementing such initiatives, as well as its implication for the motivation and performance of employees that work at these organizations (Muller et al., 2010)

Organizational culture tends to rotate around the founders' characteristics, values, and beliefs. Corporate culture is part of the fundamentals of the organization's structure that matures over several years as customs are passed from generation to generation. Changing, quantifying, and managing an organization's culture is one of the most difficult leadership challenges. Shifting an organization's culture, supporting the implementation of its strategies and policies, and promoting adaptation, goal attainment, and sustainability requires commitment and deliberate management of the change process. Most mature organizations possess discernible cultures that affect cost, performance, quality, leadership, employee involvement, process improvement, and customer focus. CMMI-DEV is one of the latest process improvement models from the Software Engineering Institute.

Organizational culture plays a significant role in a company's success or failure to adopt changes that affect people, process, and technology. Bruce Schneier, an American cryptographer, computer security & privacy specialist, and writer, popularized the "people, process, and technology" concept as the three critical factors for successful project implementation and organizational change (Banks, 2016).

Organizations need to develop and maintain quality products and services to stay competitive. Product and service quality improvement has become the differentiator in the competitive global market. Organizations that have advanced organizational culture tend to succeed in process improvement efforts. Research suggests that there are three critical dimensions that organizations should typically focus on for process improvement: people, procedures and methods, and tools and equipment (Carnegie Mellon, 2010). See *Figure 5* below.

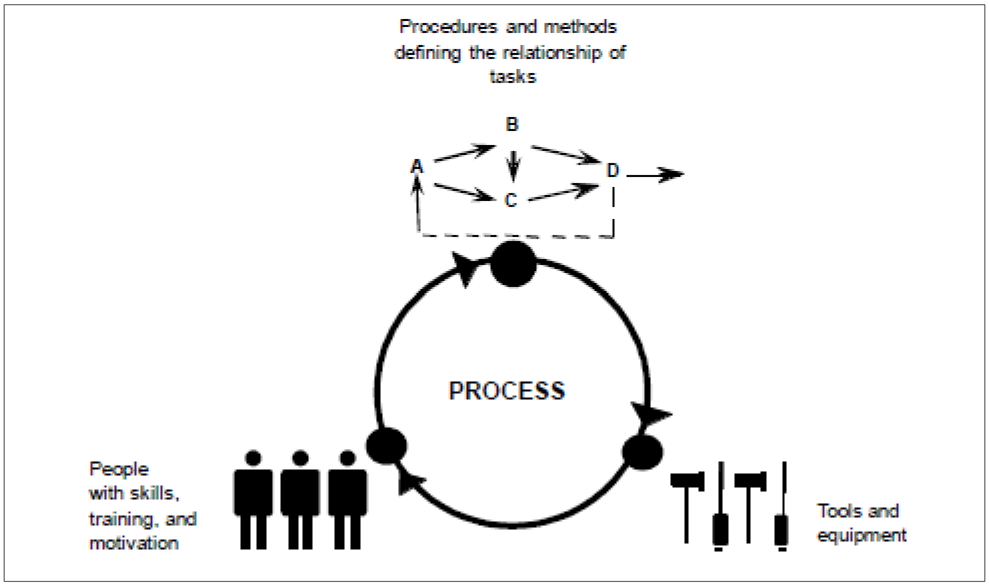

Figure 5. Three critical dimensions for process improvement (Carnegie Mellon, 2010)

Quality management started with simple inspection-based systems where workers visually check the finished products. Any poor-quality product found would be sorted into one of the three piles to be scrapped, reworked, or sold cheaply (Mahmood & Hafeez, 2013)

More complex systems evolved from these simple inspection-based systems that focused on different aspects of quality. For example, ISO 9000 is a family of standards that effectively implement and operate quality management systems (ISO 9000:2000, 2000). ISO 9000 focuses on documentation quality systems as defined by implementing processes, which differs from total quality management (TQM), which focuses on specific applications or process operations

(Crain & Wierschem, 2006). Studies have shown that ISO standards can be applied in conjunction with other process models to gain a more significant combined favorable effect. For example, a Safety Management System (SMS) can be developed and implemented using attributes inherent in the ISO 9001 QMS. (Odigie et al., 2017). It is not a secret that customer demand for quality is the most prominent reason organizations resolve to adopt ISO 9000. Crain & Wierschem 2006 contend that ISO certification can be viewed or used as a strategic competitive advantage. MacMillan 2000 (cited in Crain & Wierschem 2006) pointed out that the ISO standards and their software development provisions were incomplete.

As businesses started developing software and integrating it with other systems, there became a need for software quality assurance. This shortcoming of the ISO standards relative to software development sparked the evolution of new quality assurance measures for software development such as Bootstrap, Software Process Improvement and Capability Determination (SPICE), and the Capability Maturity Model (CMM) (Crain & Wierschem, 2006). These models were designed to help managers improve software quality and reliability, employee satisfaction, and return on investment (Mathiassen, Ngwenyama, & Aaen, 2005). By their nature, maturity models have some inherent presumptions embedded into their structure and application that influence how they are developed and applied (Mullaly, 2014). The use and adoption of models for quality certification of software processes involve using measurements that may not directly be related to the business management of software developing companies (Pedroso & Rocha de Oliveira, 2013).

Some studies have indicated recent efforts and attempts to reconcile maturity models with other standards and process frameworks, such as Projects in Controlled Environments (PRINCE2) (Luqman et al., 2008) and agile techniques such as SCRUM (Marcal et al., 2007).

Recent research has shown that organizations use agile and CMMI to compete globally (Bass et al., 2013). Vinekar & Huntley 2010 (as cited in Bass, Allison, & Banerjee, 2013) discovered that agile methods and Capability Maturity Model Integration were seen as complementary approaches in modern software development. Bass et al. (2013) argue that CMMI organizations can no longer consider agile an independent software development facet.

Cestari et al. (2013) conducted a study investigating the benefits of a formal (model-based) approach to software development projects. They specifically wanted to explore whether process maturity based on CMMI-DEV had better operations performance results (Cestari et al., 2013). CMMI from SEI has been the most used model because it's rooted in a belief that a better process would lead to better software (Mullaly, 2014). The study concluded that Maturity levels could bring better operation performance results to an organization. The study pointed out that other variables (especially regarding human factors) could influence performance.
Furthermore, these variables must be (when possible) analyzed together with more technical issues (Cestari et al., 2013). A study in a Danish software company that was CMMI level 5 certified with added agile methodology recorded a better performance improvement (Persson & Schlichter, 2015). However, Mullaly (2014) argued that the degree to which improvements in maturity lead to organizational capability and performance improvements is not precise.

Factors That Affect CMMI Maturity Level

In reviewing the CMMI literature, some research showed that the low quality of software products and processes (Walia & Carver, 2009) was why some catastrophic mishaps in product development occurred.

CMMI can be described as a model that organizations have found productive and valuable in achieving their business objectives. Some research view CMMI and Agile methods as a complementary approach in modern software development (Vinekar & Huntley, 2010)

Hwang (2012) researched using a self-assessment scheme and process improvement for continued improvement and performance. In his study, he concluded a correlation and an upward trend between continuous improvement and maturity level using the self-assessment scheme and processes in which he considered the ISO 9004:2000 guidelines.

The agile movement is the latest movement of the software industry. Galvis-Lista & Sánchez-Torres (2013) argue that agile methods for software development have an essential influence on the software industry. They pointed out that the agile methods' movement emphasizes the crucial role of the organizational culture for SDO.

Elevating CMMI certification and adopting agile methods without guaranteeing success is a best practice in closing the gap between CMMI and agile methodologies (Persson & Schlichter, 2015). When combined and used correctly, CMMI and agile methods can offer the highest return for a software development organization. CMMI organizations certified at level 3 indicate that their processes are adaptive to the team and environment, focusing on delivering a working piece of code (software) (Shelton, 2008). Shelton (2008) argues that agile by design is highly adaptable and can be modeled into CMMI-compliant software development without changing the fundamentals in the Agile Manifesto.

Software Development Methodologies

The use of software development processes has been in existence for decades. These development processes have evolved into models or methodologies (Fuggetta, 2000). A software development methodology is simply a framework to structure, plan, and control software development. (Association of Modern Technologies Professionals, 2018). The use of agile for software development has accelerated software delivery by 75% and enhanced the ability to manage changing priorities by 65% (The 12th Annual State of Agile, 2018). The following is a list of software development methodologies categories that will be used in the study:

1. Agile
    a. Agile Scrum Methodology
    b. Lean and Kanban Software Development
    c. Extreme Programming (XP)
    d. Crystal
    e. Dynamic Systems Development Method (DSDM)
    f. Feature Driven Development (FDD)

2. Waterfall

    It is also called the traditional software development life cycle. It is a linear process that follows a sequential software development that starts with requirements and ends with software delivery.

3. Other Methodologies

a. Lean development

b. Scrum development

c. Kanban development

This study focused on agile methodologies, waterfall methodologies, and other methods. Other methods are any software development methodologies other than these two. To adopt modern software development methodologies and CMMI, SDOs find themselves continually fighting between the old and new. For example, in an attempt to adopt agile and CMMI, some SDOs struggle with "the methodological rub between the waterfall-based approach used by the process improvement team and the increasingly agile-based approach used by the practitioners that were targeted for formal process improvement" (Baker, 2005).

The waterfall methodology was introduced in 1970 by Winston Royce when he first described a life cycle model in which 'testing and debugging' is identified as a separate life cycle phase (Royce, 1970).

Most SDOs move from the traditional software development paradigm to the new agile methodology. The agile methodology has gained traction quickly because it encompasses a philosophical and methodological perspective (Stoica, Ghilic-Micu, Mircea, & Uscatu, 2016). In this research, there will be a distinction between the waterfall methodology and agile methodology as a differentiator in software development methodology.

CMMI Training

CMMI training can be formal training or informal training. There are several online resources, including eLearning and Professional CMMI Training courses. These types of training are approved or recognized by SEI. Usually, an organization would provide CMMI training for anyone essential and involved in process improvement. To be part of an appraisal team, one needs to have completed the required CMMI training.

CMMI training is a process improvement training offered by the CMMI Institute, an ISACA subsidiary. The CMMI Institute offers a range of certifications, ranging from a CMMI practitioner to a CMMI appraiser. According to the CMMI Institute, the individuals receiving these certifications have obtained the knowledge required to achieve measurable results by implementing CMMI practice.

CMMI Maturity Level

The Standard CMMI Appraisal Method for Process Improvement (SCAMPI) is the official SEI method to provide maturity level ratings relative to Capability Maturity Model Integration (CMMI) models. The process to have a CMMI maturity level rating typically requires an appraisal sponsor, a lead appraiser, and an appraisal team. The appraisal sponsor comes from the organization to be appraised. The lead appraiser is an external auditor certified by the SEI who comes with the appraisal team to conduct a CMMI audit. The type of appraisal depends on the maturity level the organization is seeking. The CMMI appraisals state that for best practices, the process of improvement should be equivalent to the type of assessment used (i.e., the organization selects the ML rating to be appraised) and should provide standardized quality ratings by the CMMI (SCAMPI Upgrade Team, 2011). Using SCAMPI means the results achieved when using the appraisals should be similar. There are two different ways of appraisal for the CMMI. The staged appraisal results in one of CMMI's five maturity levels, and the continuous approach, which gives one of four levels, provides a clear definition of the concepts, contexts, and models within recognizable frameworks. Some organizations may be evaluated through their instruments or interviews for subjective measurements using quantitative techniques (Kuo, Chang, & Cheng, 2011).

There are five CMMI maturity levels from level 1 to level 5 (Chrissis et al., 2011). SEI has no certification for maturity level 1 . After an appraisal event for CMMI-DEV, an organization can be certified from level 2 to level 5 (Liou, 2011).

An appraisal event usually rates an organization's process maturity in software development into one of the four higher categories (Alyahya et al., 2012). Alyahya et al. suggest that CMMI can provide several requirements for any organization to set up software processes. The following maturity five maturity levels are defined in the SEI publications.

CMMI Maturity Level 1 - Initial

An ad-hoc, uncontrolled, mostly reactive software development approach characterizes the initial maturity level. This level has no prerequisites or defined practice areas. Success depends on the organization's capability and not on using proven processes (Chrissis et al., 2011). Despite this confusion, Maturity Level 1 organizational management teams often produce products and services that work; however, the project teams frequently exceed their budgets and schedules (Ahern et al., 2008)

CMMI maturity level 2 - Managed

The managed level indicates that some established processes can be followed. Skilled personnel with adequate resources to produce controlled outputs are employed, and relevant stakeholders are involved (Chrissis et al., 2011). Processes are controlled, monitored, reviewed, and evaluated for adherence to their process description (Chrissis, Konrad, & Shrum, 2011). The process discipline reflected indicates confirmation that existing practices are recalled during stressful times (Chrissis et al., 2011).

CMMI Maturity Level 3 - Defined

This level has established processes at the organizational level tailored to projects. According to tailoring guidelines, project teams develop their defined procedures (Chrissis et al., 2011). A critical difference between Maturity Level 2 and 3 is the scope of the organization's set of standards, process descriptions and procedures, and tailoring guidelines (Chrissis et al., 2011). At Maturity Level 3, the standards, procedures, and process descriptions for a project are tailored from the organization's set of standard processes to outfit a particular project or organizational unit and, therefore, are more reliable, except for the differences allowed by the tailoring guidelines (Kasse, 2008).

CMMI Maturity Level 4 - Quantitatively Managed

This level is tightly controlled by measuring and applying quantitative and qualitative techniques to predict future success probability. Quantitative objectives are based on the customers' requirements, organizational management teams, end-users, and process implementers (Chrissis et al., 2011). Quality and process performance are understood statistically and managed during life (Chrissis et al., 2011). At Maturity Level four, the process's performance is controlled using statistical and other quantitative techniques and is quantitatively predictable (Ahern et al., 2008).

CMMI Maturity Level 5 - Optimizing.

The optimizing level is concerned with continuous measure and improvement on optimization at the organization level. Maturity Level 5 focuses on continually improving process performance through incremental and innovative process and technological improvements (Chrissis et al., 2011). Quantitative process-improvement objectives for the organization are established, repetitively revised to reflect changing business objectives, and used as criteria in managing process improvement (Chrissis et al., 2011). The effects of deployed process improvements are measured and evaluated against the quantitative process-improvement objectives (Chrissis et al., 2011).

Based on the literature review, there seems to be a shortage of studies dealing with the impact of software development methodology, CMMI training, other process improvement standards, etc., on the CMMI maturity level. Therefore, this study attempts to address this gap in the literature.

The research on factors influencing CMMI maturity level rating provides valuable insight for organizations interested in achieving the CMMI maturity level rating. This research identified the factors that could be fed into a model that organizations involved in software development could use to reach the next maturity level. CMMI training turned out to be a significant factor in the prediction model. A CMMI is a constellation of processes that provide a conceptual framework for designing and creating high-quality software products. CMMI enhances the foundational concepts and framework based on software development practices, and provide a demonstrated ability for organizations to adapt to changing technological and economic conditions. The decentralization of organizational structure shifts the focus to meeting customer needs and delivering quality and value.

CHAPTER 3

METHODOLOGY

CMMI provides a set of practices for improving processes, resulting in a performance improvement system that paves the way for better operations and performance (Carnegie Mellon University, 2016). The goal of this research was to study the effects of software development methodology (SWDM), CMMI training (CT), and other process improvement standards (OPI), meaning other than CMMI, on an organization's CMMI Maturity Level (ML). The software development methodology focused on the method adopted for software development. There are several methodologies that SDOs have chosen to use for their software development projects. This research divided the software methodology into three categories: waterfall methodology, agile methodology, and other categories for use that did not fit in the other two types. The CMMI training was further broken into three subcategories: No CMMI training, CMMI training with certification, and CMMI training without certification. The researcher considered other process improvement standards for software development for organizations that use improvement standards other than CMMI. The data that was collected on the other standards was the number of additional standards adopted by the CMMI-appraised organization was also assigned subcategories: 0 for an organization that only focuses on CMMI, 1-2 for organizations that have at least two other improvement standards, and three or more for organizations that have more than two other process improvements standards.

These factors were analyzed and found to influence the outcome of CMMI appraisal in such a manner as to affect the CMMI maturity level rating for an organization successfully.

Sample Size

There is no specific rule of thumb to determine the sample size for statistical analysis. However, many researchers say that regression analysis should have at least 30 observations per variable. A simple formula such as $n = 100 + xi$ (x is an integer, and i represents several independent variables in the final model) was introduced as a basis of sample size for logistic regression, particularly for observational studies where the sample size emphasized the accuracy of the statistics (Bujang et al., 2018).

The formula used for the sample size for research is n = 100+30i = 100+30(3) = 190, where 30 is the number of observations per variable, and 3 is the number of independent variables.

A sample of individuals from Software development organizations, including the ones with CMMI-appraised (ML2-ML5) organizations, participated via an internet survey on a web-based questionnaire. The initial plan was for the researcher to choose 15-30 SDOs to recruit participants randomly; however, this approach could have introduced a clustering effect. Over 10,000 organizations across 106 countries have used CMMI to improve their capabilities and performance (ISACA, 2020). The researcher sent a survey to over 400 participants from various SDOs that have been appraised within the last two years worldwide. The expectation was a 50% response, which would provide over 200 of the required sample size to conduct the logistic regression.

The survey used in this research was distributed to participants from each organization and provided the study's required information by answering an online survey. The survey was used to collect the variables identified in this study using a web-based questionnaire.

CMMI Appraisal Process

Even though there are five maturity levels, SEI only awards certification from level 2 (Liou, 2011). Each maturity level provides a fundamental building block for continuous process improvement for the next maturity level (Majumdar, Ashiqe-Ur-Rouf, Islam, & Arefeen, 2011). This study focused on SDO units appraised at CMMI maturity level 2 and above and SDOs without any appraisal. The CMMI Institute has a list of current Organizations or Organizational Units that have completed and reported SCAMPI Class A appraisals against the CMMI-DEV, CMMI-SVC, CMMI-ACQ, and People CMM Models. This study focused on the CMMI-DEV model. The documented authorization has been received from the sponsor of each posted appraisal for this release of information (Published Appraisal Results, 2020).

The researcher used the quantitative approach to identify the influence and potential causal relationships among these factors that have been identified in the research questions. The ordinal regression technique was used for data analysis for this research.

Ordinal logistic regression is a technique used for predictive measures using an odds ratio calculation (Sweet & Grace-Martin, 2012). An ordinal regression model can be viewed as a generalization of binomial logistic regression. Sweet & Martin (2012) indicate that "the odds ratio is the coefficient with the log removed." The odds ratio is a measure of how many times higher the odds of occurrence are per each one-unit increase in the independent variable (Sweet & Grace-Martin, 2012). For example, each one-unit increase on the independent variable scale increases the dependent variable's odds by a factor equal to the calculated odds ratio. The ordinal regression analysis technique helps determine how the independent variable(s) can predict the dependent variable (Gau, 2013).

Research Design

The researcher used ordinal regression to evaluate and determine how the maturity level rating category is different when the three independent variables, software development methodology, CMMI training, and process improvement standards, are considered. The three independent variables used have levels as follows: software development methodology variable has three levels – waterfall, Agile, and other. The CMMI training variable has three levels – no training, training with certification, and training without certification. Other process improvement standards category also has three levels - 0, 1-2, and 3 or more. Ordinal regression can be used to model the ordinal dependent variable's outcome with categorical independent variables, including variables that have multiple levels. The researcher verified that the data met the ordinal regression assumptions and could be analyzed using ordinal regression. These assumptions were: (1) The dependent variables are ordered. (2) One or more independent variables are either continuous, categorical, or ordinal. (3) No multicollinearity. (4) Proportional odds.

This researcher designed an internet survey targeted at SDOs, including the ones registered on the Published Appraisal Results website (sas.cmmiinstitute.com/pars). The participants were required to be software project managers or sponsors who participated in an appraisal event for other organizations.

Research Purpose

This research aimed to explore the effects on CMMI level rating and the interactions between factors of software development methodology, CMMI training, and other standards. CMMI-DEV has provided the solution for tracking past projects' success in a competitive market for software developing companies. Measurement processes such as CMMI have provided organizations with a framework and enabled these organizations to establish and institutionalize a set of measurements for software development processes (Pedroso & Rocha de Oliveira, 2013)

By studying the interactions between factors that have been identified in this study, organizations can optimize these factors and be configured for the most successful improvement and quality. This study's results can help SDOs decide which maturity level to seek when requesting CMMI maturity rating appraisal.

Research Strategy

The researcher investigated the effect on CMMI maturity level outcome based on the three independent variables. The researcher collected data and information for the variables from a web-based questionnaire. The researcher sought permission from the Indiana State University Institutional Review Board (IRB). The protocol for contacting participants for an academic research study/project and the corresponding consent forms were completed and followed. The researcher got SDOs, including the ones listed on the CMMI appraisal report website, through the points of contact (POC) supplied or used in the organization's public information to establish a connection with the targeted organization. The researcher communicated the study's intention and provided all necessary information to the POCs to decide whether to participate.

Research Approach

The researcher's data was transferred to SPSS for coding and analysis. The researcher quantified and subjected the data to statistical treatment to support or refute "alternate knowledge claims" (Creswell, 2011).

Ordinal regression was used with ordinal dependent variables, and the independent variables can be categorical or continuous covariates. Some experts refer to ordinal regression models as cumulative logic models. All the variables used in this research were either ordinal or nominal. Ordinal regression primarily uses the logit link function even though other link functions are available to the model. Yet some call ordinal regression with a logit a proportional odds model. The odds model reference is because the model may have independent variables that have levels. The independent variable's parameters or regression coefficients are independent of the ordinal dependent variable's levels (categories). As in logistic regression, these coefficients may be converted to odds ratios (Garson, 2014). The proportional odds model was used for this research for assumption testing.

Ordinal Regression

Ordinal regression or ordinal logistic regression predicts an ordinal dependent variable given one or more independent predictors or factors. The power of ordinal regression can determine the dependent variable's independent variables' statistical significance. The ordinal logistic model for a single independent variable is then

$$\ln(\theta) = \alpha + \beta X \quad (1)$$

When there are k independent variables, then (1) becomes

$$\ln(\theta) = \alpha + (\beta_1 X_1 + \cdots + \beta_k X_k) \quad (2)$$

α is the intercept, X_k are set of factors or predictors, $\beta_1 \ldots . \beta_k$, are the regression coefficients for each threshold and are assumed to be the same. These coefficients are given in log-odds units. α is the intercept, and it's generally written as β_0. From here on β_0 will be used to denote the intercept.

Proportional Odds Model

The proportional odds model is the odds ratio of the event, independent of the category j for the dependent variable. There is an assumption that the odds ratio is constant for all categories of the dependent variable. The proportional odds model aims to simultaneously consider the effects of a set of independent variables across these possible consecutive cumulative splits to the data (O'Connell, 2011).

For this research, the dependent variable maturity level contains five categories. An organization can be in one of the five categories at one given time; in other words, an organization cannot belong to more than one maturity level at the same time. Under this apportioning of data, the researcher would be interested in identifying the factors associated with the increased likelihood of belonging to the lowest-rated category (ML1) rather than being beyond type ML1 to the next higher maturity level categories ML2 through ML5. For any of the explanatory variables, it is possible to calculate the odds of being at ML1. This cumulative concept will continue to the last category, ML5, which will always occur. The researcher used this cumulative progression for the four distinct ordinal response categories.

The following is the math behind the proportional odds model. This mathematical model only applies to data that meet the proportional odds assumption. The proportional odds assumption is that the number added to each of these logarithms to get the next is the same in every case. In other words, these logarithms form an arithmetic series (UCLA, 2021).

$$\text{logit}(\text{p1}) \equiv \log \frac{\text{p1}}{1 - \text{p1}} = \beta 0 + \beta x$$

$$\text{logit}(\text{p1} + \text{p2}) \equiv \log \frac{\text{p1} + \text{p2}}{1 - \text{p1} - \text{p2}} = 2\beta 0 + \beta x$$

$$\text{logit}(\text{p1} + \text{p2} + .. + \text{pk}) \equiv \log \frac{\text{p1} + \text{p2} + .. + \text{pk}}{1 - \text{p1} - \text{p2} - .. - \text{pk}} = k\beta 0 + \beta x$$
$$and\ p1 + p2 + \cdots + pk = 1$$

The logit coefficients in ordinal regression are in log-odds and therefore cannot be read as regular coefficients. They are used to predict the probabilities of a maturity rating.

Table 2 Factor maturity level mapping

Rating	coefficients	Simplified
ML1	$\log(\frac{p1}{(p2+p3+p4+p5)})$	Odds being in ML1
ML2	$\log(\frac{(p1+p2)}{(p3+p4+p5)})$	Odds being in ML2
ML3	$\log(\frac{(p1+p2+p3)}{(p4+p5)})$	Odds being in ML3
ML4	$\log(\frac{(p1+p2+p3+p4)}{(p5)})$	Odds being in ML4
ML5		Otherwise ML5

Statistical Package for the Social Sciences (SPSS) ordinal regression procedure extends the general linear model to ordinal categorical data. The researcher can specify five link functions as well as scaling parameters. The link function is the probability function resulting in a linear model in the parameters (Norusis, 2012).

Ordinal regression was used for this study with the application of a proportional odds model. There are three independent variables with three levels to be analyzed using the ordinal regression method in SPSS. An α=0.05 was used for rejecting or failing to reject the null hypothesis.

This choice of α=0.05 of significant level specifies the probability of the result being representative of reality. The researcher will default to the common practice of rejecting the null hypothesis when the significant level is less than or equal to 0.05 (Box, Hunter, & Hunter, 2005).

It is possible to build a model in the ordinal regression technique to check for both main and interaction effects even when using the ordinal and categorical data types. The research incorporated a model that checks for these interactions per the research questions.

Ordinal Regression Assumptions

1. The dependent variable (DV) should be measured at the ordinal level
2. One or more independent variables (IV) are continuous, ordinal, or categorical
    a. IV – Software development methodology (Agile, waterfall, other)
    b. IV - CMMI Training (None, training w/ certification, w/o certification)
    c. IV – Other standards (0, 1-2, 3or more).
3. There is no multicollinearity
4. Proportional odds assumptions

Sources of Data/Instruments

Study variables, scales of measurement, variable type, and data source are detailed in *Table 5* variables, scales of measurement, and variable type. The table defines and operationalizes dependent and independent variables: CMMI maturity level, software development methodology, CMMI training, and other process improvement standards.

Table 3 variables, scales of measurement, and variable type

Variable	Scales of Measurement	Variable Type
CMMI maturity level (CML)	Ordinal	DV
Software development methodology (SDM)	Nominal (categorical)	IV
CMMI training (CT)	Nominal (categorical)	IV
Other process improvement standards (OPI)	Nominal (categorical)	IV

RQ1: Does software development methodology (SDM) affect CMMI maturity level?

Hypothesis 1: H_{01}: There is no difference in the CMMI maturity level whether the SDM is agile, waterfall, or other.

$\beta_{SDM} = 0$ {β is the regression coefficient, and SDM is an independent variable (IV) with three categorical values: agile, waterfall, or other.}

H_{A1}: There is a difference in the CMMI maturity level when SDM changes from agile to waterfall or other.

$\beta_{SDM} \neq 0$

RQ2: Does CMMI training affect CMMI maturity level?

Hypothesis 2: H_{02}: There is no difference in the CMMI maturity level whether the CMMI training levels are: no training, training with certification, and training without certification.

$\beta_{CT} = 0$ {CT: no training, training with certification, and training without certification}

H_{A2}: The CMMI maturity level changes when the CMMI training level changes from no training to training with certification or training without certification.

$\beta_{CT} \neq 0$

RQ3: Do Other process improvement standards affect CMMI maturity level?

Hypothesis 3: H_{03}: There is no difference in the CMMI maturity level regardless of the number of other process improvements adopted.

$\beta_{OPI} = 0$ {OPI: None, 1-2, 3 or more}

H_{A3}: There is a difference in the CMMI maturity level with at least one other process improvements adapted.

$\beta_{OPI} \neq 0$

RQ4: Is there a two-way interaction in Software development methodology, CMMI training and other process improvements with regard to CMMI maturity level?

Hypothesis 4: H_{04}: There is no two-way interaction between Software development methodology, CMMI training, and other process improvements on CMMI maturity level.

$\beta_{OPI\_SDM} = \beta_{OPI\_CT} = \beta_{CT\_SDM} = 0$

H_{A4}: There is a two-way interaction between Software development methodology, CMMI training, and other process improvements on CMMI maturity level.

At least one in (β_{OPI_SDM}, β_{OPI_CT}, β_{CT_SDM}) $\neq 0$

Data Collection Administration

The researcher designed the questionnaire used to collect data for this research. The IRB reviewed the questionnaire, and approval was granted. The questionnaire was made available to the Qaultrics server, and a link was sent to participants for data collection.

Data Analysis Techniques

Quantitative research involves numerical data analysis, which lets the researcher test the hypotheses (Rovai, Baker, & Ponton, 2014). The researcher used numerical statistical analysis, which allowed the researcher to test the hypotheses presented herein. It involved some descriptive statistical analysis; however, this research's focus was the statistical significance of the relationships between the independent variables and the dependent variable of CMMI maturity level rating. The researcher performed quantitative data analysis using the IBM SPSS Statistics Software using the ordinal regression technique.

To start with, the researcher applied the theoretical framework of ordinal regression to find any statistical significance of the independent variables software development methodology (SDM), CMMI training (CT), and other process improvements (OPI) on the dependent variable maturity level (ML).

The basic concepts discussed with single-level predictors were extended to predictors with multiple levels for this research.

$$\ln(\mathrm{ML}) = \beta 0 + (\beta \mathrm{SDM} \times \mathrm{SDM} + \beta \mathrm{CT} \times \mathrm{CT} + \beta \mathrm{OPI} \times \mathrm{OPI} + \beta \mathrm{OPI\_SDM} \times \mathrm{OPI} \times \mathrm{SDM} + \beta \mathrm{OPI\_CT} \times \mathrm{OPI} \times \mathrm{CT} + \beta \mathrm{CT\_SDM} \times \mathrm{CT} \times \mathrm{SDM}$$

ML categorical response, SDM nominal explanatory variable with three levels (Agile, waterfall, other), CT nominal explanatory variable with three levels (no training, training with certification, and training without certification}), OPI nominal explanatory variable with three levels (None, 1-2, 3 or more)

Limitations of Methodology and Ethical Consideration

Since this research involved multiple companies, the researcher provided a cover letter stating the study and assured the participants that the information research would not ask for competition-sensitive information.

Limitations of Methodology.

There is a possibility that one or more assumptions for ordinal regression may be violated. For example, if the proportional odds assumption is violated. The researcher followed the recommended procedures for assumption violation for the technique. The violations were not to the level where the researcher may have needed to use nonparametric analysis methods.

Ethical Consideration.

There was no data that was coded or manipulated to skew the results. The researcher did not collect any personal information and, respected the participants' anonymity and confidentiality, which provided feedback on the survey.

CHAPTER 4

RESULTS

This chapter represents data analysis based on the data collected through the web-based questionnaire. There were nine items that required the respondent to select a response from the list of choices and six items that allowed the user to type in a response if it was not on the list. The main aim was to capture the factors that could influence the CMMI maturity rating during an appraisal event. The entire study was conducted using an online survey configured and managed through the Qualtrics web-based survey system. The researcher then used the currently published appraisal results to randomly select over 400 SDOs to choose participants from around the world. According to ISACA's website (https://cmmiinstitute.com/pars), the Published Appraisal Results System (PARS) represents most but not all CMMI Appraisals that have resulted in a rating. This data set only includes data made public by originators. The online PARS included the Sponsor's name, the Appraisal Team Leader (ATL) name and the ATL's contact information (email).

An email was sent to the CMMI ATL for the selected SDOs with the participation requirements and instructions on accessing the survey. A sample of the email is provided in *Appendix B*. The ATL was the point of contact for the survey email and would distribute it to members of their organization. The target was 2000 participants, with the assumption that the 400 ATLs would share the survey link within their SDO and an average of 5 participants would answer the survey from each SDO. That would have exposed 2000 participants to the study. There were no restrictions on one participant to one SDO; there could be multiple participants within the same

SDO. There was no tracking mechanism for identifying and mapping the participants to a specific SDO. The window for data collection was from January 2020 to April 2020. There was a poor response rate, with 119 participants responding to the survey, and completed responses were 109 only.

Basic Requirements of Ordinal Logistic Regression

1. The dependent variable (DV) should be measured at the ordinal level
2. One or more independent variables (IV) are continuous, ordinal, or categorical
   a. IV – Software development methodology (Agile, waterfall, other)
   b. IV - CMMI Training (None, training w/ certification, w/o certification)
   c. IV – Other standards (0, 1-2, 3or more).
3. There is no multicollinearity
4. Proportional odds assumptions

The researcher checked assumptions #3 and #4 using SPSS Statistics.

Determining Multicollinearity

Multicollinearity occurs when two or more independent variables have a high correlation. When independent variables are highly correlated, it becomes difficult to determine which predictor variable contributes to the dependent variable's explanation.

The independent variables were coded to test for multicollinearity.

SPSS was used to generate the coefficients table that contained the Tolerance and the Variance Inflation Factor (VIF). A VIF of greater >10 is a cause for concern (UCLA, 2021). The VIF values for the independent variables were below ten, as seen in Table 3 Collinearity Statistics.

Table 4 Collinearity Statistics

Coefficients[a]

Model		Collinearity Statistics Tolerance	VIF
1	OPI=NoStds	.917	1.091
	OPI=1to2 Stds	.903	1.107
	CT=NoTraining	.932	1.073
	CT=WnoCert	.913	1.096
	SDM=Wfall	.113	8.811
	SDM=Agile	.114	8.807

a. Dependent Variable: CML

Table 4 Test of Parallel Lines has the test's information to test the proportional odds assumption. The null hypothesis states that the location parameters (slope coefficients) are the same across response categories. The odds for each explanatory variable are consistent across the different thresholds of the outcome variable. The odds for each explanatory variable are the same from going through the maturity levels. The statistically significant result suggests that the odds differ between the different thresholds.

Since the ordered logit model estimates one equation over all response variables, the test for proportional odds tests whether the one-equation model is valid. If the null hypothesis is rejected based on the significance of the Chi-Square statistic, the conclusion would be that the ordered logit coefficients are not equal across the outcome levels, and a less restrictive model would be fitted (UCLA, 2021) . Fail to reject the null hypothesis, conclude that the assumption holds. For this model, The assumption of proportional odds was met, as assessed by a full likelihood ratio test comparing the fit of the proportional odds location model to a model with varying location parameters, $\chi 2(12) = 16.357$, $p = .175$

Table 5 Test of Parallel Lines

Test of Parallel Lines[a]

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Null Hypothesis	68.743			
General	52.386	16.357	12	.175

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.

a. Link function: Logit.

Descriptive Statistics

The questionnaire contained an item that would help the researcher identify the geographical location of the survey participants. *Figure 6* shows participants' composition from organizations participating in the CMMI maturity level rating by geographical location.

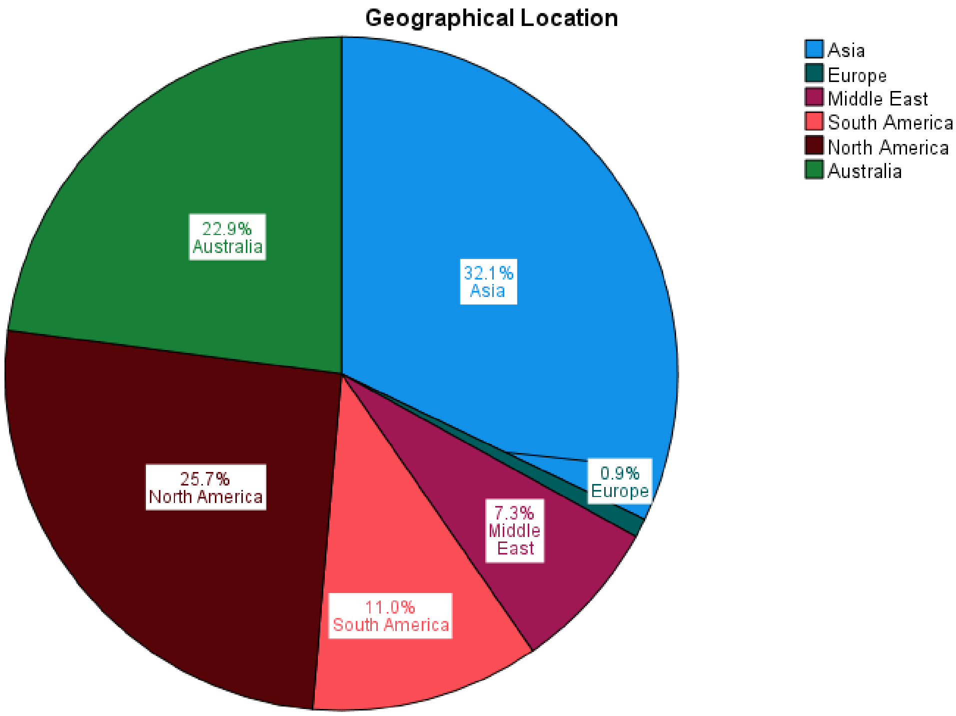

Figure 6 Geographical Location of participants

The researcher wanted to capture the roles of the various participants in their SDOs. There was an item that allowed the participants to indicate their role within the SDO. Most respondents indicated they were from the software, systems, and hardware departments. In *Figure 7*, 33.0% of the valid responses reported that they were supervisors in the software/systems/hardware departments. 61.5% of the valid responses reported being practitioners, and the other 5.5% were non-technical.

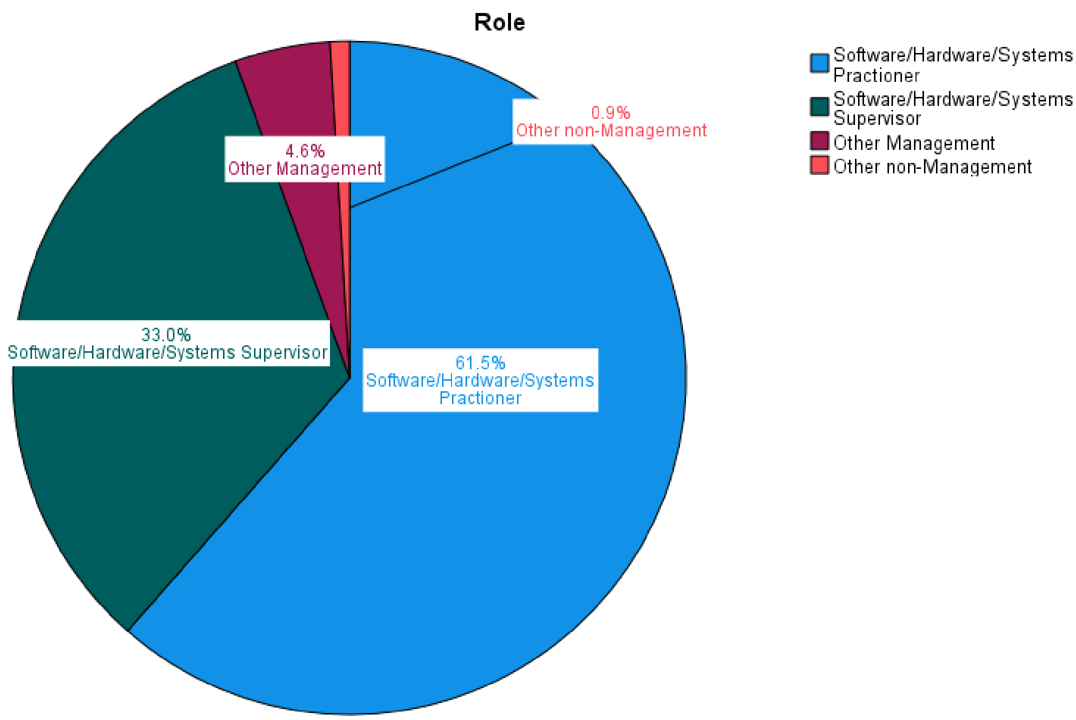

Figure 7 Role of Participant in the Organization

The researcher was interested in capturing the areas the participants supported within their SDOs. There was an item that allowed the participants to choose the area they supported. The survey results indicated that 55.0% of them supported the software department, and 39.4% reported that they supported systems. The remaining participants indicated that they supported hardware or other. See *Figure 8*

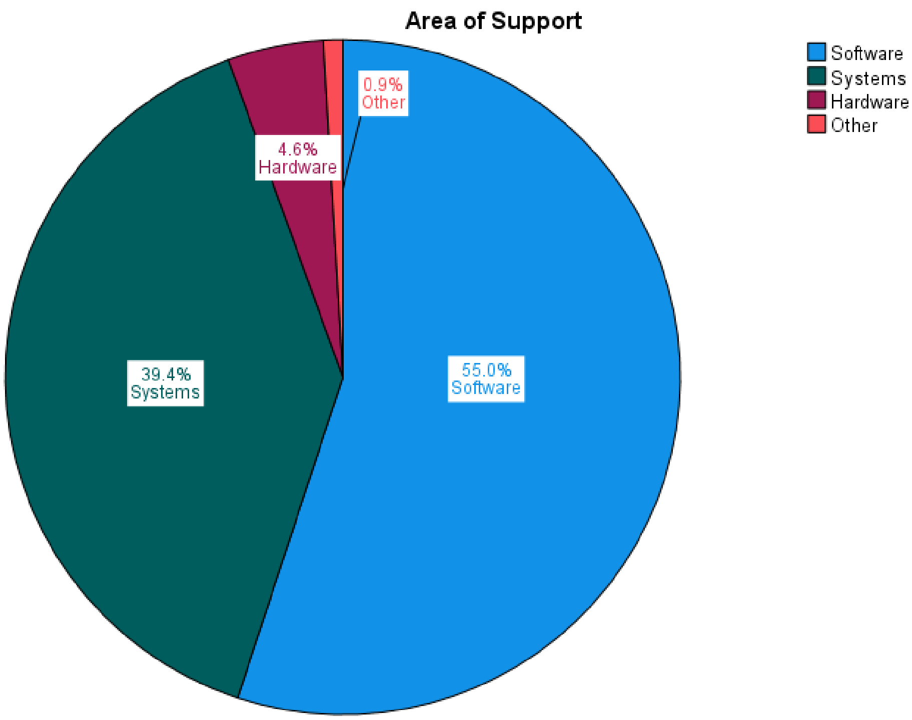

Figure 8 Participant's Area of Support

Another item that the researcher thought might be interesting to the study was the number of years a participant had worked in the field. The results for this item indicated a high representation of experienced participants. Only 7.3% of the participants answered that they had less than a year of experience, while 45.9% of the participants fell into the 1 to 5 years category. The rest (46.8%) of the participants had more than five years of experience, as shown in *Figure 9*.

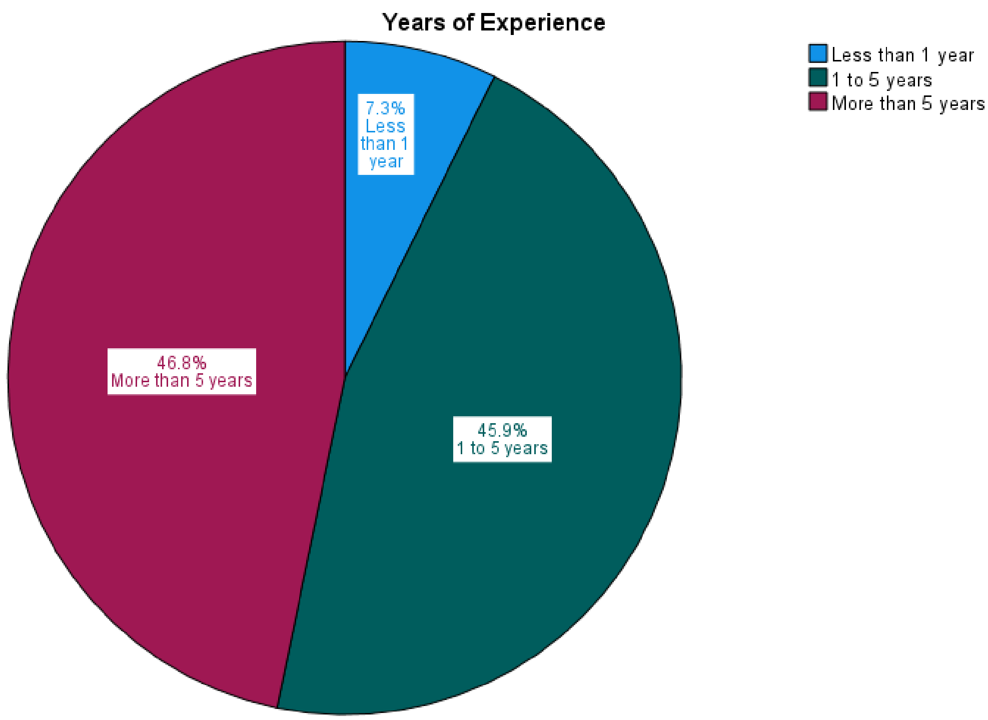

Figure 9 Participant's Years of Experience

Another variable that the researcher wanted to capture was the size of the SDOs. There was an item in the survey that allowed the participants to identify the size of their SDO. Most participants were from organizations with 101-500 employees, accounting for 61.5% of the valid responses. 22.0% answered that their organizations had less than or equal to 100 employees. 16.5% also answered that they belonged to organizations that had over 500 employees. See *Figure 10*.

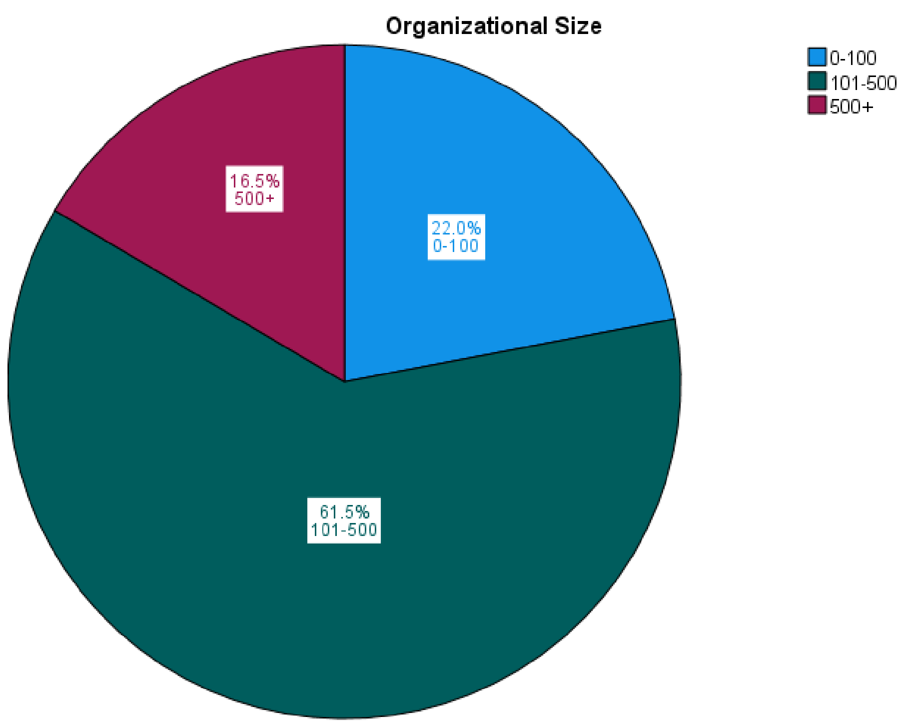

Figure 10 Organizational Size

A request was submitted to over 400 SDOs for participation in the survey, and 119 respondents provided feedback. However, only 109 observations were valid. The small sample size of 119 and the valid observations of 109 increase the type II error and may skew the results or have less statistical power. The results of the findings can be used to draw conclusions on the sample and not the general population. The researcher cleaned the data using some recommended methods (International Business Machines Corporation, 2022). The researcher removed the rows that were completely blank. The missing values were replaced using the technique of replace by nearby median. In this table, the researcher was modeling software methodology's effect on CMMI Maturity level while moving along the three software methods: Agile, water, and others.

CMMI Maturity Level

The CMMI maturity levels range from level 1 to level 5. There is no appraisal for maturity level 1. Formal appraisal starts at maturity level 2, and in the collected data, there were no participants that indicated that their SDO was at level 1. Therefore, in this analysis, the lowest maturity rating is maturity level 2 or ML2. Since there is no rating for maturity level 1, the type of ordinal regression for this research will produce an equation for each one of the J-2 cumulative logits, where J is the number of categories of the ordinal dependent variable. There are five categories for the maturity level rating ML, however, sincere the is no rating for ML1, there will be three cumulative logits and three equations. There were four research questions that needed to be answered, and the data collected was to be used to answer those questions. The following table is a Test of Model Effects, and it can be used to answer the first three research questions. The SPSS Test of Model Effects tables is used to establish whether the variable is statistically significant overall before exploring any specific contrasts reported in the Parameter Estimates table.

Table 6 Table of Test of Model Effects

Tests of Model Effects

Source	Type III Wald Chi-Square	df	Sig.
SDM	2.638	2	.267
CT	8.177	2	.017
OPI	.797	2	.671

Dependent Variable: CML
Model: (Threshold), SDM, CT, OPI

Table 6 presents the results of models' effects test. It shows that CT is the predictor whose effect is significant on predicting the CMMI maturity level because of p-value =0.017 < 0.05. Table 7 presents the logit regression estimation of the parameters

Table 7 Table of Parameter Estimates

Parameter Estimates

Parameter		B	Std. Error	95% Wald Confidence Interval		Hypothesis Test			Exp(B)	95% Wald Confidence Interval for Exp(B)	
				Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
Threshold	[CML=ML2]	-3.288	1.6555	-6.533	-.044	3.945	1	.047	.037	.001	.957
	[CML=ML3]	1.804	1.6305	-1.392	5.000	1.224	1	.269	6.073	.249	148.353
	[CML=ML4]	2.262	1.6336	-.940	5.464	1.917	1	.166	9.602	.391	235.964
[SDM=Agile]		1.872	1.6028	-1.270	5.013	1.364	1	.243	6.500	.281	150.379
[SDM=WaterFall]		2.333	1.6321	-.866	5.532	2.044	1	.153	10.311	.421	252.678
[SDM=Other]		0[a]	.	.	.	.	.	.	1	.	.
[CT=NoTraining]		-2.505	1.7130	-5.863	.852	2.139	1	.144	.082	.003	2.345
[CT=Traning w/o Cert]		-1.159	.4340	-2.010	-.309	7.135	1	.008	.314	.134	.734
[CT=Training w Cert]		0[a]	.	.	.	.	.	.	1	.	.
[OPI=No Stds]		-.570	.6610	-1.866	.725	.744	1	.388	.565	.155	2.066
[OPI1-2 Stds]		-.217	.5160	-1.228	.794	.177	1	.674	.805	.293	2.213
[OPI=3 or More Stds]		0[a]	.	.	.	.	.	.	1	.	.
(Scale)		1[b]									

Dependent Variable: CML
Model: (Threshold), SDM, CT, OPI

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

Research Questions, Hypotheses

RQ1: Does software development methodology (SDM) affect CMMI maturity level?

Table 6 above shows the results of models' effects test for the SDM variable using the Wald test statistic. The table shows that the overall effect of the SDM variable is not statistically significant, $\chi2(2) = 2.638$, $p = .267$; that is, SDM does not have a statistically significant effect on the dependent variable. Therefore, fail to reject the null hypothesis, that states that there is no significant difference between CMMI maturity level and software development methodology SDM (is agile, waterfall, or other).

RQ2: Does CMMI training affect CMMI maturity level?

Table 6 above shows the results of models' effects test for the CMMI training (CT) variable using the Wald test statistic. The table shows that the overall effect of the CT variable is statistically significant, $\chi2(2) = 8.177$, $p = .017$; that is, CT has a statistically significant effect on the dependent variable. The type of CMMI training has a statistically significant effect on the prediction of CMMI maturity level, Wald $\chi2(2) = 8.177$, $p = .017$. Therefore, reject the null hypothesis.

However, Table 6 does not explain which or how the different types of training affect CMMI Maturity level rating. Table 7 is used to examine the coefficients produced by SPSS Statistics in the Parameter Estimates table. From the information from Table 7, it can be concluded that the $CT_{\text{No training}}$ is not statistically significantly different from the $CT_{\text{TrainingwCert}}$

(which is the omitted, or reference, category), but $CT_{Training w/o Cert}$ is statistically significantly different from $CT_{Training\ wCert}$ with a p-value of .008.

From Table 7 above on the CT estimate for SDOs with no CT training, the results indicate a likelihood of SDOs falling into a lower maturity level rating when compared to CT training with certification. Similarly, an SDO with training but no certification is likely to fall into a lower maturity rating when compared to an SDO with CT training with certification.

The coefficients in Table 7 can be used to calculate cumulative predicted probabilities from the logistic model for each case for when CT is no training.

$$P(ML = 2\ |CT = 1) = \frac{1}{1 + e^{(3.288+2.505)}} = 0.003$$

$$P(ML = 2\ or\ 3|CT = 1) = \frac{1}{1 + e^{(-1.804\ +2.505)}} = 0.332$$

$$P(ML = 2\ or\ 3\ or\ 4|CT = 1) = \frac{1}{1 + e^{(-2.262+2.505)}} = 0.440$$

$$P(ML = 2\ or\ 3\ or\ 4\ or\ 5|CT = 1) = 1$$

From the above estimated cumulative probabilities for each maturity level, the probability for each maturity level category can be calculated when CT is no training.

P(ML2)=0.003

P(ML=3) =0.332-0.003= 0.329

P(ML=4) =0.440-0.332= 0.108

P(ML=5) =1-0.440= 0.560

Similarly, the probabilities for the other levels of training can be calculated. When CT is training without certification, the following are the results.

P(ML2)=0.012

P(ML=3) =0.656-0.012= 0.644

P(ML=4) =0.751-0.656= 0.095

P(ML=5) =1-0.751= 0.249

For the reference category, when CT is training with certification.

P(ML2)=0.036

P(ML=3) =0.859-0.036= 0.823

P(ML=4) =0.906-0.859= 0.047

P(ML=5) =1-0.906= 0.094

In the output, SPSS Statistics automatically creates dummy (indicator) variables for categorical variables, such as the CMMI training variable. By default, the last category is used as the reference category. The effect of the first two categories of the CT variable are separately compared to the last category; that is, the effect of no training is compared to training with certification (Training w Cert), and training without certification (Training w/o Cert) is also compared to Training w Cert. Unfortunately, this essentially precludes obtaining the effect of Training w Cert on the dependent variable.

RQ3: Do Other process improvement standards affect CMMI maturity level?

Table 6 above shows the omnibus test result for the OPI variable using the Wald test statistic. The table shows that the overall effect of the OPI variable is not statistically significant, $\chi2(2)$ = .797, p = .671; that is, OPI does not have a statistically significant effect on the dependent variable. Therefore, fail to reject the null hypothesis that states: There is no difference in the CMMI maturity level regardless of the number of other process improvements adopted.

RQ4: Is there a two-way interaction in Software development methodology, CMMI training and other process improvements with regard to CMMI maturity level?

The collected data was insufficient to carry out a two-way interaction analysis.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

This study included an evaluation of factors that affect the CMMI maturity level rating in SDOs. The study included an extensive literature review, data collection using an online survey, and a detailed data analysis. The researcher used the data collected to perform descriptive statistical analysis using a qualitative approach. The outcome was a ranked CMMI maturity level based on some factors of CMMI training, Software methodology, and other process improvement. The sample size needed for the research was 190. The researcher recruited more than 400 participants by email. There were only 119 respondents who participated in the survey. Only about 109 responses were valid. A few participants exited the survey for some reason, and others did not complete the survey for some reason.

Overall, this study found that the CMMI training significantly predicted the next CMMI maturity level. However, the independent variables CT and SDM were not significant in predicting the CMMI maturity level rating. The research complemented the previous study by using qualitative research methods to investigate the effects of software methodology on CMMI rating.

Research Questions, Hypotheses, and Findings

Unexpected Results

There were a variety of unexpected results in this research. The proposed original hypotheses seemed like they would be easily supported and backed up by research. The available literature seemed to indicate some high levels of participation and interest. It turns out that obtaining access to a CMMI population was not as easy as originally thought. This could perhaps be a reasonable explanation for why there is not much quantitative research in this area. The response rate was very low; therefore, this study's results only apply to the sample and cannot be used to generalize to the larger population.

RQ1: Does software development methodology (SDM) affect CMMI maturity level?

The researcher concluded that there was no statistical significance for the SDM factor on maturity level rating. This could be due to the insufficient sample data that was collected. The lack of statistical significance of SDM effect on the CMMI maturity level rating is surprising. Some of the data indicated that some participants failed to correctly identify the type of methodology used. Some participants selected waterfall methodology and indicated in a different question that their primary methodology was scrum practice or agile method.

RQ2: Does CMMI training affect CMMI maturity level?

The results suggest that the CMMI maturity level rating has a relationship with the level of CMMI training. The CMMI training – training without certification was found to be statically significant in predicting the next CMMI maturity level on the sample used. However, due to the small sample size, the researcher could not generalize the results to the larger population. The data seem to suggest that many of the participants did not have certified CMMI training. This is in line with Galvis-Lista & Sánchez-Torres (2013) that indicated that most of the CMMI training was organizational and did not require a formal certification.

RQ3: Do other process improvement standards affect CMMI maturity level?

The OPI parameter estimates indicated no statistical significance on CMMI maturity level when OPI was considered.

RQ4: Is there a two-way interaction in Software development methodology, CMMI training and Other process improvement standards with regard to CMMI maturity level?

The collected data was insufficient to carry out a two-way interaction analysis.

Fulfillment of Research Purpose

The purpose of this research was to explore the relationship between CMMI level rating and the factors of software development methodology, CMMI training, and process improvement standards. SDOs are under constant pressure to demonstrate successful past performance in their products and services sustainment and development.

The data analysis indicated a relationship between the CMMI maturity level rating and SDM and CT. These findings have laid a foundation and a need for further investigation, perhaps including other factors like the organization's size.

This research could help academic researchers who may want to explore other factors that affect the CMMI maturity level rating. The review of literature highlights the lack of coverage of this subject. This research could also provide a roadmap to evaluate an organization's financial cost and benefit from moving from one CMMI maturity level to another.

Recommendations for Further Research

Many of the results obtained from this study were unexpected. Obtaining access to the CMMI organizations was not as easy as initially thought. The lack of easy access to CMMI organizations could be an indicator as to why there is not a great deal of research in this area. One could seek to find answers and perhaps suggest how these firms can participate more in such kind of research.

This research could be a foundation for further investigation and how to extend CMMI to other industries. The study can help researchers interested in narrowing it down to a specific software development methodology. The researcher can further relate the software development methodology and enable businesses to react better to changing market conditions and product development to market times.

CMMI has been around for over thirty years and remains relevant as a foundation framework for software development and improvement framework. It was created for the DoD to assess the quality of software developers for defense contracts. DevOps is a new software methodology and framework not considered in this study. Even though SDM was not significant in this study, future researchers should consider a DevOps-CMMI alignment.

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Appendix A : Data Collection Questionnaire

Definitions:

CMMI Maturity level: This is an organizational level rating based on appraisal results after completion of a CMMI audit. The levels range from maturity level (ML) 1 through 5. If your organization is not rated, please chose ML1

Agile methodology: This is any method that uses an iterative approach to software development, including

1. Agile Scrum Methodology
2. Lean and Kanban Software Development
3. Extreme Programming (XP)
4. Crystal
5. Dynamic Systems Development Method (DSDM)
6. Feature Driven Development (FDD
7. Other iterative approach to software development

Waterfall: Traditional software development process that follows phases of conception, initiation, analysis, design, construction, testing, deployment, and maintenance.

Other methodologies: Any software methodology that is not agile or waterfall.

In this organization...	***Response***
1. What is your geographical location	☐ North America ☐ South America ☐ Central America/Caribbean ☐ Australia/Oceania ☐ Africa/Middle East ☐ Europe/Russia ☐ Asia/Pacific
2. How big is your organization	☐ 0-100 ☐ 101-500 ☐ 500+
3. What is your organization's current CMMI maturity level (ML) rating?	☐ CMMI level ML1 (or Not rated) ☐ CMMI level ML2 ☐ CMMI level ML3 ☐ CMMI level ML4 ☐ CMMI level ML5
4. When is the last time your organization was appraised/rated (provide the year)	o Year_________
5. Does your organization make announcements when you are about to be appraised	☐ Yes ☐ No
6. Does your organization announce the CMMI level rating appraisal results to the employees	☐ Yes ☐ No

In this organization...	***Response***
7. What area do you support	☐ Software ☐ Systems ☐ Hardware ☐ Other
8. What is your role in your organization?	☐ Project manager ☐ other (Specify)________________
9. *(Pertaining to software development)* Which of the following software methodologies are used in your organization/project – Select the primary methodology for your project	☐ Agile methods ☐ Waterfall methods ☐ Other (specify)_________________
10. How long has the organization been using this methodology?	o Number of years__________
11. Which methodology was primarily used before the adaption to this methodology	o NA o Methodology ________________
12. How many years of experience do you have in your current role?	☐ Less than 1 ☐ 1-5 ☐ more than 5
13. *(Pertaining to software development)* What is your level of CMMI training	☐ No CMMI training ☐ CMMI Training without certification ☐ Formal CMMI Training with certification

In this organization...	***Response***
14. Please provide information on CMMI training for your team members in your current project. Write down the number of employees that have	☐ No CMMI training________________ ☐ CMMI Training without certification_______ ☐ Formal CMMI Training with certification_______
15. *(Pertaining to software development)* Which of the following quality standards are used in your organization? *Select all that apply*	☐ ISO series_____ ☐ ASQ _____ ☐ Lean Processes____________ ☐ TQM______________ ☐ Six Sigma________________ ☐ COBIT_________________ ☐ Other (Specify)___________________________
16. Do you have other quality improvements certifications that are applicable to your organization	☐ Yes ☐ No

Appendix B :Sample email

Sakawa Ogega
Indiana State University
200 N 7th St
Terre Haute, IN 47809

My name is Sakawa Ogega and I am a PhD Candidate at Indiana State University, College of Technology. I am conducting research to determine whether the software methodologies, other process improvement standards, and CMMI training has an effect on the CMMI maturity level rating for CMMI-DEV for software for Software Development organizations like yours.

There is information in literature and research that indicates that these independent activities could potential influence the outcome of maturity level rating. This is important if your organization is seeking a higher maturity level appraisal leveraging this independent activity could boost your organization to the next level of CMMI. It is possible that your organization could qualify for a higher maturity level without the additional cost to your organization that may be associated with the higher maturity level appraisal.

Your participation in this survey is anonymous and strictly voluntarily, but important. The information you provide will be held in strict confidence, and you will not be asked to provide any personally identifiable information or information that will identify your organization.

To complete the survey, please click the link in this e-mail. If desired, you may copy it into your preferred browser.

The study results will provide valuable information to you and your organization. If you have an interest in the results, I will be glad to send you a summary. The link also allows the participants to view results or a summary view of the data upon completion of the survey.

Please feel free to contact me at sogega@indstate.edu should you have any questions. If you would like a copy of the study results, please contact me at the above e-mail with "study results" as the subject line.

Thank you for the invaluable assistance you will provide by completing this survey.

The link:

Sincerely,

Sakawa Ogega

Appendix C IRB Approval

Indiana State University
More. From day one.

Institutional Review Board

Terre Haute, Indiana 47809
812-237-3088
Fax 812-237-3092

DATE:	January 20, 2020
TO:	Sakawa Ogega, PhD
FROM:	Indiana State University Institutional Review Board
STUDY TITLE:	[1488999-2] Evaluating the Influence of Some Factors on Capability Maturity Model Integration for Development (CMMI-Dev) Maturity Level
SUBMISSION TYPE:	Revision
ACTION:	DETERMINATION OF EXEMPT STATUS
DECISION DATE:	January 20, 2020
REVIEW CATEGORY:	Exemption category # 2

Thank you for your submission of Revision materials for this research study. The Indiana State University Institutional Review Board has determined this project is EXEMPT FROM IRB REVIEW according to federal regulations (45 CFR 46). You do not need to submit continuation requests or a completion report. Should you need to make modifications to your protocol or informed consent forms that do not fall within the exempt categories, you will have to reapply to the IRB for review of your modified study.

Internet Research: If you are using an internet platform to collect data on human subjects, although your study is exempt from IRB review, ISU has specific policies about internet research that you should follow to the best of your ability and capability. Please review Section L. on Internet Research in the IRB Policy Manual.

Informed Consent: All ISU faculty, staff, and students conducting human subjects research within the "exempt" category are still ethically bound to follow the basic ethical principles of the Belmont Report: 1) respect for persons; 2) beneficence; and 3) justice. These three principles are best reflected in the practice of obtaining informed consent.

If you have any questions, please contact Anne Foster within IRBNet by clicking on the study title on the "My Projects" screen and the "Send Project Mail" button on the left side of the "New Project Message" screen. I wish you well in completing your study.