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Impact of Capability Maturity Model Integration on Performance of Information System Projects in Western Province of Sri Lanka

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ABSTRACT

This study attempts to examine the impact of the Capability Maturity Model Integration (CMMI) levels on the performance of software projects in western province of Sri Lanka to fill the lack of empirical gap in the literature. A quantitative approach was adopted since the study tests hypotheses based on the positivist approach. Data were collected from eighty-two software development firms via a self-administered questionnaire and inferential analysis was performed for data analysis using the multiple regression and One-way Anova. Results indicate that CMMI levels do have different impacts on software project performance and higher CMMI levels are highly associated with improving software project performance in Sri Lanka. Specifically, CMMI level III (managed) indicates the highest impact than CMMI levels II (defined) and IV (quantitatively managed). Results imply that software process activities are documented, standardized, and integrated into a standard software process for developing, testing, and maintaining the application for projects across the organization. The present study strengthened empirical findings in developing economies and provides practical implications for the diverse stakeholders to uplift CMMI levels to enhance the quality, efficiency, and productivity of software projects in Sri Lanka. Moreover, since the study only focused on the software development organizations in western province of Sri Lanka, further studies would strengthen the generalizability of the findings.

Keywords: CMMI, Project Performance, Software projects, Sri Lanka

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INTRODUCTION

Technology can be defined as applying scientific knowledge for practical purposes, especially in industry. Therefore, information technology is defined as "The technology used for the study, understanding, planning, design, construction, testing, distribution, support, and operations of software, computers, and computer-related systems that exist for Data, Information, and Knowledge processing" (IF4IT, 2009, p.12). Information Technology (IT) benefits the business world by allowing organisations to work more efficiently and maximise productivity (Lorin & Eric, 1996). Faster communication, electronic storage, and records protection are advantages that IT can have on your enterprise (Lorin & Eric, 1996). Information technology involves computer applications, on which nearly every work environment is dependent. Since computerised systems are widely used, it is advantageous to incorporate IT into organisations. Information technology is a modern phenomenon that has dramatically changed the daily lives of individuals and businesses throughout the world. IT is vital to company operations, and leveraging it for business success is a key to survival in the modern business. It plays an integral role in every industry, helping companies improve business processes, achieve cost efficiencies, drive revenue growth, and maintain a competitive advantage in the marketplace (Chirantan, 2005). In short, they are the repositories for critical and sometimes highly proprietary corporate information. The improper access to or the destruction of these resources will have serious consequences for the Company. The strategic use of IT can help organizations increase their competitive advantage and make considerable improvements in operating performance (Nicholas, 2004).

Developing a business strategy with an IT component that is aligned with business objectives and is supported by sound business justification will enable organizations to improve performance, increase productivity, and serve customers more effectively. It will also help mitigate the risks involved with technology decisions. Information Communication Projects have a high rate of failure, and some projects are critical. Software project cancellation and failure rates increase day to day due to technical failure, lack of end client acceptance, quality failures, and also the lack of proper management (Gamage, 2017). Inadequate testing resources are one of the major factors that cause poor quality, which creates risk for a project (Rajkumar & Alagarsamy, 2013). For example, in 2005, Hudson Bay Co., Canada, lost $33.3 million due to an inventory system problem, and the UK Inland Revenue tax credit overpaid $3.45 billion due to software errors (Charette, 2005). These types of errors and failures cause profit loss or project cancellations in organizations. Due to software project failures and cancellations, customers will have to bear high financial losses (Gamage, 2017). Project failure depends on three incidents: how failure is defined, the type of project being studied, and the stage of the project's life cycle at the time it is assessed (Pinto & Mantel, 1990).

Most companies allocate nearly 4%- 5% of annual revenue for their information technology (Charette, 2005). If the invested projects fail it could damage the company's growth. Organizations are trying to achieve project performance and success by adopting methodological approaches. Methodology is a set of predefined guidelines or principles that can be specific approaches, templates, forms, and checklists used over the project life cycle (Charvat, 2003). Software project management methodologies are used in the software industry to achieve project performance. A project is a temporary endeavor undertaken to create a unique product, service, or result (A Guide to the Project Management Body of Knowledge: PMBOK, 2013). The temporary nature of projects indicates a definite beginning and end. The end is reached when the project objectives have been achieved when the project is terminated because its objectives will not or cannot be met, or when the need for the project no longer exists. Moreover, some companies use their own best practices tools, and techniques IT IT-related project management. These tools, techniques, and best practices can be more effective than the standards and methodologies used in the Software Development Industry. For example, Project Management's best practices are a novice Java developer training roadmap, extracting from a schedule in an MS Excel spreadsheet (grant chart), and a High-level MS (Microsoft) Project Schedule, etc.

Nowadays, Information system projects are much more important than in earlier days. Most organizations have Project Management Office (PMO) in their organizations, and the main responsibility of the PMO is aligning projects with project management methodologies (Project Management Institute, 2013). It is expected to identify the importance of practicing project management standards as measured by Capability Maturity Model Integration (CMMI) levels. The CMMI Product Suite was developed by the CMMI Product Team, a team of process improvement experts from the government, industry, and the SEI (Software Engineering Institute), to improve on the existing Software Capability Maturity model (SW-CMM) released in 1991. The application of project management practices can be measured by using CMMI, and project performance can be measured by using achievement software schedule, budget, and scope. The degree of standardization can be measured by the CMMI level of a particular company. Many companies measure their success in part due to business processes and procedures developed but not widely adopted because software process standardization needs to be certified against standards and it will cost the company. Most software development companies are startups, and they do not like to invest more in certifications at the initial stage, whereas stable companies are invested in standards like CMMI. This is especially true for the software development industry. Worldwide, the software industry has largely adopted the Carnegie Mellon Software Engineering Institute's process for software development, called CMMI, for Capability Maturity Model Integration. The CMMI process can be applied to most businesses, but it has proven particularly effective for developing software. In Sri Lanka, Topmost IT Related organizations like Virtusa (Pvt) Ltd, MphasiS (Pvt) Ltd, hSenid, X-ONT Software (Pvt) Ltd (hSenid, 2015) and also, and Dialog Axiata PLC have been certified CMMI.

Organizations in developed and developing countries usually use methodologies like CMMI levels to measure the performance of ICT projects developed by them (Paulk et al., I993). Studies are focused on empirical research to emphasize the contribution of CMMI models to the success or failure of ICT projects. However, in Sri Lanka, the usage of these types of methodologies is very lacking in the ICT industry to measure the success or failure rate of their projects (Kapurubandara, Lawson, 2006). Therefore, present study attempts fill this research gap by answering the main research problem of “Is there a significant relationship between CMMI Levels and the performance of ICT projects and how performance varies with CMMI levels?”. Accordingly, the study aims to examine the impact of CMMI levels and the performance of software projects in Sri

Lanka. Moreover, the study intends to achieve the following specific objectives:

- To examine the existing project management methodologies currently used in the information technology industry for the management of projects.
- To identify whether there is a significant relationship between CMMI Levels and the performance of ICT projects, and measure how performance varies with CMMI levels.
- Identify the project management standards, methodologies, and best practices in the ICT industry.

LITERATURE REVIEW

Project Management Standards (PMS)

To assess the PM performance on individual construction projects, we must first determine the correct, best, and suitable project management standards for projects. There are many standards and methods for PM practices: The Project Management Body of Knowledge (PMBOK) by the Project Management Institute, the IPMA Competence Baseline (ICB) by the International Project Management Association, ISO 9000, Prince2 by The Office of Government Commerce UK, the Capability Maturity Model, the Project and Program Management (P2M) by the Engineering Advancement Association of Japan, and the C-PMBOK by the Chinese PM conference, among others.

The PMBOK by PMI

The project Management standard consists of nine knowledge areas and five process groups. The nine knowledge areas are: integration, scope, cost, time, quality, risk, human resources, communication, and procurement (Sanjuan & Froese, 2013). The process groups are: initiating, planning, executing, monitoring and controlling, and closing (Project Management Institute, 2013). Each PM process defined within these knowledge areas and process groups is described in terms of its inputs, tools and techniques, and outputs. Project integration management is a key knowledge area because it involves the coordination of all management activities. Project integration management includes the authorization of the project (project charter), the PM plan (construction schedule, human resource plan, quality plan, risk plan, communication plan, and procurement plan), the execution, monitoring, controlling, and closing of the project, and the change control process.

International Project Management Association Competence Baseline (IPMACB)

The IPMACB version 3 standard is represented in the 46 competence elements that are grouped into contextual competencies (11 elements), technical competencies (20 elements), and behavioral competencies (15 elements) (International Project Management Association, 2012). The contextual competencies include the project, program, and portfolio orientation and implementation with the organization's strategy. It also includes the permanent organization, business case, systems, products, technology, finance, and legal aspects. Contextual competencies state clearly the importance of the project on the broader picture of the organization. This competence area also includes personnel management, which may be part of the behavioral or technical competence considering its definition. The behavioral competencies are personal skills and attributes a project manager should have to contribute to project success. These behavioral competencies include leadership, engagement, motivation, self-control, assertiveness, relaxation, openness, creativity, result orientation, efficiency, consultation, negotiation, conflict and crisis, reliability, values appreciation, and ethics (Trivellas & Drimoussis, 2013). The technical competencies include elements that are either knowledge-based or PM processes. PM success should not be considered a technical competence since it is more of the result of being competent. As defined by the ICB3 standard, "a competence is a collection of knowledge, personal attitudes, skills, and relevant experience needed to be successful in a certain function." Within the technical competencies, the following competencies can be considered part of human resource management: project organization, teamwork, problem resolution, project structures, and resources. Similarly, the following technical competencies can be considered as part of communication management: reports (control & reports), information and documentation, communication, and interested parties.

ISO 9000

The ISO 9000 family of standards (ISO 9000) is related to quality management and quality assurance. The ISO 9000 standard is intended to provide an understanding of the concepts and definitions in the family of 9000 standards. ISO 9001 is related to the requirements of a quality management system and certification process. ISO 9004 provides the framework for continuous improvement and the satisfaction of employees, owners, suppliers, partners, and society in general (Kathryn et al., 2004). The ISO 9000 standards are based on the principles of customer focus, leadership, involvement of people, process approach, system approach to management, continual improvement, factual approach to decision making, and mutually beneficial supplier relationship (Derrick, 2018). To successfully implement a quality management system, the ISO 9000 process approach includes management responsibility, resource management, product realization, and measurement, analysis and improvement (Sanjuan & Froese, 2013).

PRINCE2

PRINCE2 stands for projects in a controlled environment. PRINCE2 is a PM method based on a continued business justification and a planning process focused on products. It is the result of the accumulated experience from good and bad projects. It is a method that gives fundamental importance to roles and responsibilities within the project, and management by stages and with defined deviation tolerances on cost, time, quality, scope, risk, and benefits (Office of Government Commerce, 2009). PRINCE2 has themes that are similar to the PM knowledge areas of the PMI standard or to the technical competencies of the IPMACB3 standard, for instance, quality, plans, and risk. The organization theme could be part of a broader knowledge area, such as human resource management, or part of the IPMACB3 contextual competence. The business case and change themes could be part of the integration management knowledge area or the contextual competencies on the IPMACB3 standard. The progress theme is more like a process than a knowledge or skill.

The Variety of Standards for Project Management

With a new standard such as ISO 21500, it will always need to be checked how well it can solve problems and how likely its rapid proliferation is. There are plenty of project management standards with very different origins. Generally, different types of standards are used for different occasions (see Figure 1) (Grau, 2013). It will be important to compare the new standard to the already existing ones.

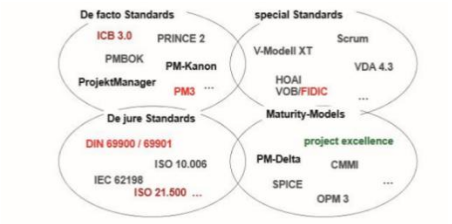

Figure 1*: Different type of Project Management Standards*

Source: *(Grau, 2013)*

Levels of Capability Maturity Model Integration (CMMI)

Capability Maturity Model (CMM) was initially developed by the Software Engineering Institute (SEI) in the mid-1980s, and it has been improved since then. The CMM was initially funded for military research. A maturity level is a well-defined evolutionary plateau toward achieving a mature software process. Each maturity level provides a layer in the foundation for continuous process improvement. The CMM is similar to ISO 9001, one of the ISO 9000 series of standards specified by the International Organization for Standardization (ISO). The ISO 9000 standards specify an effective quality system for manufacturing and service industries: ISO 9001 deals specifically with development and maintenance. The main difference between the two systems lies in their respective purposes: ISO 9001 specifies a minimally acceptable quality level for software processes, while the CMM establishes a framework for continuous process improvement and is more explicit than the ISO standard in defining the means to be employed to that end.

Levels of CMMI

Level One: Initial

The software process is characterized as inconsistent, and occasionally even chaotic. Defined processes and standard practices that exist are abandoned during a crisis. The success of the organization majorly depends on individual effort, talent, and heroism. The heroes eventually move on to other organizations taking their wealth of knowledge or lessons learned with them.

Level Two: Defined

This level of Software Development Organization has basic and consistent project management processes to track cost, schedule, and functionality. The process is in place to repeat the earlier successes on projects with similar applications. Program management is a key characteristic of a level-two organization (CMMI Product Team, 2010).

Level Three: Managed

The software process for both management and engineering activities is documented, standardized, and integrated into a standard software process for the entire organization, and all projects across the organization use an approved, tailored version of the organization's standard software process for developing, testing, and maintaining the application (CMMI Product Team, 2010).

Level Four: Quantitatively Managed

Management can effectively control the software development effort using precise measurements. At this level, the organization sets a quantitative quality goal for both software process and software maintenance. The performance of processes is controlled using statistical and other quantitative techniques and is quantitatively predictable (CMMI Product Team, 2010).

Level Five: Optimizing

The Key characteristic of this level is focusing on continually improving process performance through both incremental and innovative technological improvements. At this level, changes to the process are to improve the process performance and at the same time maintain statistical probability to achieve the established quantitative process-improvement objectives (CMMI Product Team, 2010).

Levels of Capability Maturity Model Integration (CMMI) are illustrated in Figure 2.

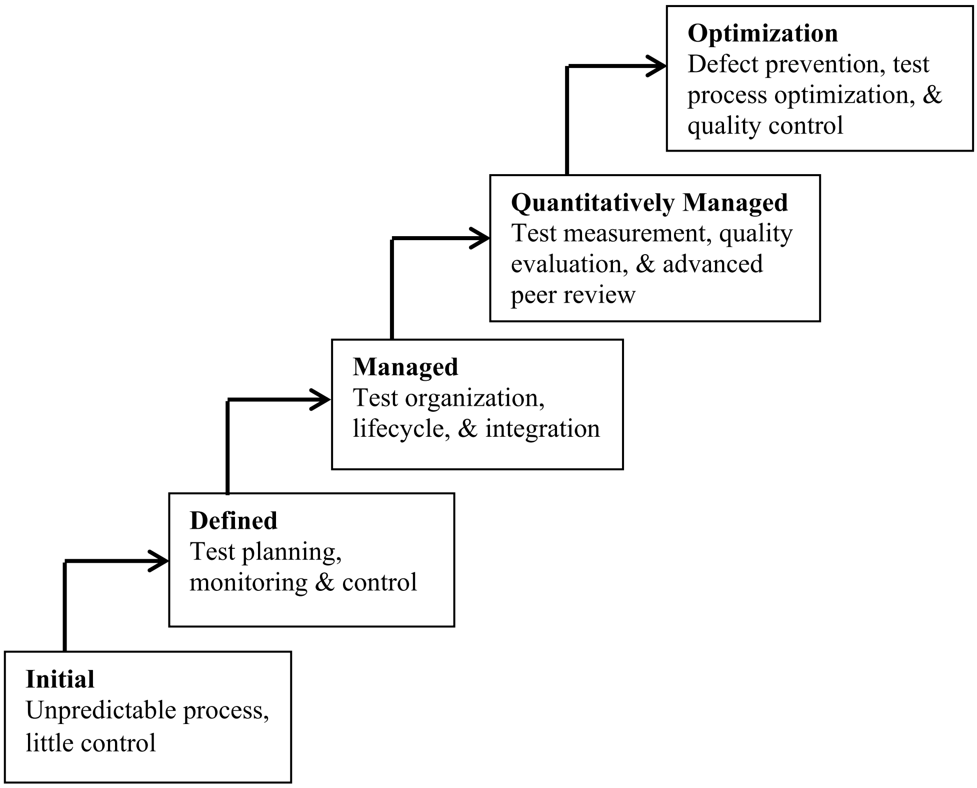

Figure 2: *Levels of Capability Maturity Model Integration*
Source: *CMMI Product Team, 2002, Capability Maturity Model Integration, pp. 10*

Project Performance

Project performance can be a composite of several aspects. Most researchers agree on three dimensions of project performance such as meeting schedule, meeting budget, and meeting user requirements (McFarlan, 1981). Some other studies suggest further dimensions of project performance including the amount of work produced, the quality of work produced, and the ability to meet project goals (Deephouse, 1995). Henderson and Lee (1992) contended that software project performance needs to be measured through its efficiency, effectiveness, efficiency, and timeliness. Moreover, amount of work produced, the quality of work produced, and the ability to meet project goals is certain criteria to determine the software project performance (Jones, & Harrison, 1996).

Impact of CMMI Levels on Project Performance

Nino Grau (2013) highlighted that ISO 21500 is considered a flexible project management standard for more than one occasion, and PM will therefore apply the basic PM Standards as the basis of their work to gain the freedom to achieve excellence in their project work through innovative and creative approaches. Mohagheghi and Jørgensen (2017) highlighted that larger projects were not perceived by the clients to be more problematic than smaller ones and given high priority and good support by top leaders is most important for project success. All of the projects suffered from poor project management due to the lack of project management experience of the project manager, less estimated skills of PM, the business background of the project manager, and the Software development background of the project manager (Verner et al; 2008). Nguyen et al., (2010) found that there is a relationship between CMMI levels and cycle time in ICT Projects. Levels of CMMI improve the process of projects and improve the return on investment of IT projects (Saeed et al., 2017). Gunasena (2016) found that higher levels of CMMI enhance software project performance.

CMMI increases project efficiency, productivity, performance, and the consistency of the program in software projects in developing countries (Hou et al; 2021; Abdel Rahman et al; 2023). Based on the empirical findings, especially in developing economies which are illustrated in Table 1 disclosed that software projects need to establish initial CMMI levels and gradual improvement is needed in order improve the project performance such as cost reduction, quality improvement, productivity enhancement, completing the project within the schedule, economies of scale, customer satisfaction etc. However, literature further disclosed that lack of infrastructure, skills, and expert knowledge are some of the challenges faced by developing economies in achieving the standards of software projects. In the context of Sri Lanka, only one empirical research study could be found, which is mostly relating to the present study conducted by Gunasena (2016). In addition to the findings of this previous study, the present study provide new insights to the existing literature in the Sri Lankan context through presenting a more detailed quantitative analysis and to what extent the software projects in Sri Lanka applied standardized project management practices to fill the empirical gap. Moreover, most of the previous research has applied quantitative methods based on numerical data. Thus, it is important to apply more qualitative studies as well in order to have an in-depth understanding of the phenomena.

Table 1: *Previous Studies on the Relationship between CMMI Levels and Software Project Performance*

Author/s & Year	Topic	Findings	Methodology	Country
Hou et al., (2021)	Enhancement of the Capability Maturity Model for Improving the Quality of Software Projects in Developing Countries	Tech industry in developing economies cannot cope with the foreign market due to the underlying causes of failure of novice and professional workers, unpractised software developers, and software engineers are ignorant of the CMMI model. Further,	Quantitative method	Pakistan

		CMMI is efficiency-oriented		
Laitinen et al., (2024)	Productivity development enablers in the infrastructure sector: capability maturity model integration approach	To enhance the productivity of IT infrastructure sector, infrastructure productivity development (iProDe) CMMI model was developed.	Qualitative method	Finland
Saeed et al., (2017)	The Impact of Capability Maturity Model Integration on Return on Investment in IT Industry: An Exploratory Case Study	As a result of CMMI implementation, project could reduce the overall product cost, enhance quality, reduce the completion of project time, enhance customer satisfaction, and increase return on investment	Mix method	Pakistan
Oliveira et al., (2010)	A comparative analysis of CMMI software project management by Brazilian, Indian and Chinese companies	The study found a certain hierarchy amongst the companies from the three countries. Regarding the development of software projects (factor 1) and software quality and productivity (factor 2), it was found that the Chinese companies had a more positive view of CMMI than their Indian counterparts, who were in turn more upbeat than the Brazilian respondents, who were the least enthusiastic about CMMI	Quantitative	Brazil, India, and China
Gunasena (2016)	Effects of Capability Maturity Model on Project Performance of Information and Communication Technology Projects	Findings indicate that different CMMI levels have different impacts on software project performance and higher CMMI levels improve software project performance.	Quantitative	Sri Lanka

Singh & Gill (2020)	Measuring the Maturity of Indian Small and Medium Enterprises for Unofficial Readiness for Capability Maturity Model Integration-based Software Process Improvement	Indian software SMEs have been following CMMI and accepted it though not officially but informally. These SMEs are continuously moving towards process improvisation and standardization. By achieving CMMI Level-III informally, SMEs with more than five years of their establishment has suggested a positive move towards maturity.	Quantitative	India
Omol et al., (2024)	Digital Maturity Assessment Model (DMAM): assimilation of Design Science Research (DSR) and Capability Maturity Model Integration (CMMI)	Digital maturity assessment model was developed for SMEs by integrating CMMI levels to enhance performance. The prototype effectively supports SMEs in assessing their digital maturity.	Quantitative	Kenya
Padma et al., (2008)	An Exploratory Study of the Impact of the Capability Maturity Model on the Organizational Performance of Indian Software Firms	Results found that most of the firms find it easier to set standards than to improve further. Moreover, financial gains are not immediate, and firms must strive to continuously improve in order to gain financially from CMMI implementation. CMMI has a significant positive change on organizational performance.	Quantitative	India
Abu-Baker et al., (2019)	The Impact of the Implementation of Capability Maturity Model Integration on User Satisfaction: Case Study on	The results concluded that there is a direct effect of implementing CMMI on customer satisfaction and software quality. It also	Quantitative	Jordan

	Software Companies in Jordan	shows that higher software quality positively affects customer satisfaction, as well as software quality plays a mediation role between the effect of CMMI implementation and the customer satisfaction.		
Alyahya et al., (2012)	Impact of CMMI-Based Process Maturity Levels on Effort, Productivity and Diseconomy of Scale	The results revealed that each higher CMMI maturity level has a considerable impact in decreasing the development effort, increasing the productivity rate and reducing the diseconomy of scale. The results also indicate that adoption of CMMI-based process improvement for software organizations that are developing projects of large sizes.	Quantitative	Malaysia

Source: *Authors Compiled*

Based on the literature review, a conceptual framework is illustrated in Figure 2 and the study hypothesizes that;

H1: Organizations in different levels of CMMI (CMM II, CMM III, and CMM IV) exhibit different levels of information systems project performance.

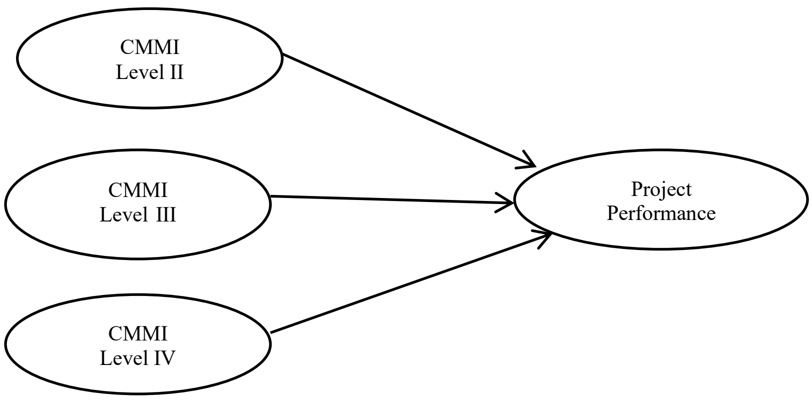

Figure 2: *Conceptual Framework*

RESEARCH METHODOLOGY

Research Design

This study used deductive approach because the research aimed at testing hypotheses based on the developed theory (Sekaran & Bougie, 2011). The present study can be considered descriptive since it attempts to describe the state of CMMI levels and study the effect of CMMI levels on the performance of IT projects in Sri Lanka. This research study is cross-sectional as the data are collected from the respondents at a particular point in time. The study applied a quantitative research design and analyzed data with statistical procedures to establish the relationship between variables. Accordingly, CMMI levels are considered as independent variables and the dependent variable is project performance.

Population and Sample

The target population for the present study is software development organizations in the ICT industry in the Western province of Sri Lanka. Western province was selected since the capital city is belongs to the western province and most of the top level software organizations are located in the western province of Sri Lanka (Wijeratne, 2014). According to the Sri Lanka Association for Software and Services Companies (SLASSCOM) (2016), there are 225 registered software development organizations established in Sri Lanka. A total number of 150 software developers are listed in the Excel registry, which is considered as the sampling frame of the study. The target sample was selected from the software developers who are working in reputed software companies located in western province since most of these companies have software project management office and a software project manager or related experts. First, questionnaires were sent to these 150 software development companies. However, due to the low response rate, again questionnaires were sent to the computer science graduates in the 2007-2008 batches' group mail through University of Colombo, by using snowball sampling method. Altogether 81 questionnaires were received and usable for data analysis. G power application software was used to calculate the required sample size of the study. Accordingly, the total sample size was given as 81 (Effect size=0.5, Number of groups = 3) for the one-way ANOVA test as illustrated in Figure 3.

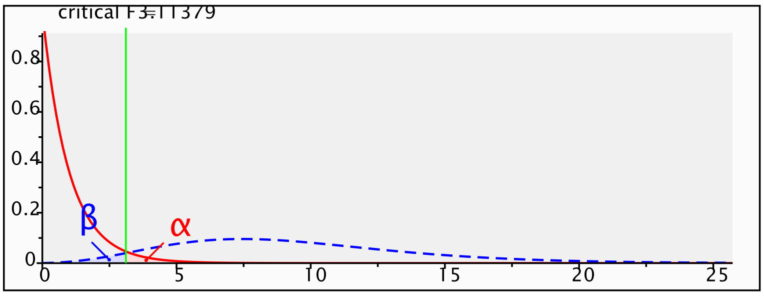

Figure 3: *G power output*

Source: Survey data

Operationalisation of Variables

The scales used to measure the CMMI levels and project performance were taken from previous literature developed by Delkleva and Drehmer (1997). A total of 38 items obtained from Delkleva and Drehmer (1997), were used to measure CMMI levels. These 38 items can be separated into three different groups and each group represents different activities that could be conducted in different levels of CMMI (the first 12 for CMM II, 13–26 for CMM III, and 27–38 for CMM IV) and 6 items were used to measure the project performance including the completion of the project within the scheduled time, complete the project within the budget, achieving project goals, quality standard, customer satisfaction, and meet the sponsors requirements who are actively involved with the project. Some statements were deployed without any changes while certain statements were slightly changed for easy understanding. Five-point Likert scale was used to rate the CMMI levels and project performance.

Data Collection and Analysis

The present research utilized both primary and secondary sources for data collection. The questionnaire was used as the primary data collection technique of this study. A semi-structured questionnaire was developed and checked with two experts in the field. A standard questionnaire was used to determine the CMMI Levels and validated through a pilot study. Some questions were removed after conducting the pilot study due to complexities in project performance indicators. The questionnaire includes a profile of the organisation and questions to test the independent and dependent variables of the proposed model, as CMMI level II, CMMI level III, CMMI level IV, and the performance of the IT Projects. The target respondents are the software developers who are working in software development organisations in the western province of Sri Lanka. An Internet survey was conducted, and 150 questionnaires were sent via e-mail to the drawn sample with an explanation of the research. Two reminders were also sent to the sample of respondents who did not respond on the due date to increase the response rate. Finally, 81 filled questionnaires were received yielding a 54 % response rate. Further, researches compared the responses of early and late respondents and confirmed that there were no significant differences exist in independent and dependent variables. Moreover, the data were collected from the respondents at once as a cross-sectional study in order to have an initial understanding of the relationship between independent and dependent variables. Moreover, secondary data were collected from already existing sources such as reports, journal articles, books etc. in order to have a clearer understanding of the theoretical concepts, practices, and empirical research relating to the phenomena.

Descriptive statistics, regression analysis, and one-way ANOVA is used to analyze data to test the hypothesis and achieve the research objectives.

Reliability and Validity

In order to measure the reliability of the constructs, Cronbach's alpha value was utilized. In accordance with Table 1, the Cronbach's alpha values of all constructs are above 0.7 indicating that there is high internal consistency among the items used in the constructs. Content validity and construct validity are widely applied in many studies and refer to "the assessment of the correspondence of the variables to be included in a summated scale and its conceptual definition" (Hair et al, 2014). Thus, content validity was ensured by the use of more items to represent the constructs through previous studies, and also expert opinions were taken from two experts in the field, and pre-tested with 10 respondents.

Table 1: *Reliability Statistics*

Construct	Number of items	Cronbach's Alpha
Project Performance	6	.940
CMMI Level II	12	.949
CMMI Level III	14	.939
CMMI Level IV	12	.944

Source: *Survey data*

Convergent validity refers to the degree to which items of a construct are correlated with each other (Malhotra & Birks, 2007). Convergent validity is higher when the inter-item correlation between the items of a scale is greater than 0.50, and average variance extracted (AVE) based on the factor loadings above 0.50, which are tested through confirmatory factor analysis. Discriminant validity refers to "the extent to which a construct is truly distinct from other constructs" (Hair et al., 2014,).

Discriminant validity is established when there is a low correlation between two scales. In the present study, discriminant validity was assessed by comparing the square root of the correlation estimates with the AVE value (Hair et al. 2014). Evidence of divergent validity was provided as the square root of the correlation estimate was lower than AVE values between those constructs (AVE > r^2 confirms discriminant validity).

RESULTS

Profile of the Respondents

The sample consists of the majority of male respondents (78%) and females (22%) respondents. Out of all the respondents, 47% of the organizations are adapted to standardized project management practices, whereas 25% of the organizations are sometimes used standardized project management practices. Further, 50% of organizations are in CMMI level III, 27% of the organizations are in CMMI level II, and 23% of the organizations are in CMMI level IV which is the highest level of CMMI in this study.

Normality of the Data

Normality tests are used to determine whether a data set is modelled for normal distribution. Skewness and Kurtosis values are used to determine the Normality of the data. The acceptable ranges for skewness or kurtosis are below +1.5 and above -1.5 (Tabachnick & Fidell, 2013). Accordingly, the skewness and kurtosis values of the variables are at an acceptable level. Table 2 presents the skewness and kurtosis values of the research data.

Further, the Kolmogorov-Smirnov (K-S) test is also a goodness-of-fit measure for continuous scaled data. It tests whether the observations could reasonably have come from the normal distribution. The results of the Kolmogorov Smirnov Test are illustrated in Table 3 which indicates that significant values of project performance (dependent variable) and project management standards (independent variable) are 0.667 and 0.984 respectively. It is concluded that since both variables are significant, data are normally distributed.

Table 2: *Skewness and Kurtosis of Constructs.*

Variable		Statistic	Std. Error
CMMI II	Skewness	0.165	0.293
	Kurtosis	-0.899	0.578
CMMI III	Skewness	-0.364	0.293
	Kurtosis	-0.579	0.578
CMMI IV	Skewness	-0.606	0.293
	Kurtosis	0.118	0.578
Project Performance	Skewness	-0.228	0.266
	Kurtosis	-0.621	0.526

Source: *Survey data*

Table 3: *Kolmogorov Smirnov Test*

		Pp_Sum_Final	Independent_ Sum_Final
N		82	82
Normal Parameters[a,b]	Mean	52.2317	136.8659
	Std. Deviation	12.59659	25.74604
Most Extreme Differences	Absolute	.080	.051
	Positive	.060	.036
	Negative	-.080	-.051
Kolmogorov-Smirnov Z		.726	.459
Asymp. Sig. (2-tailed)		.667	.984

Source: *Survey Data*

Multicollinearity can be assessed by examining tolerance and the Variance Inflation Factor (VIF) (Jeffrey, 2015). If a low tolerance value like less than 0.1 is accompanied by large standard errors and non-significance, multicollinearity may be an issue. According to the multicollinearity test, the rule of thumb is tolerance should be greater than 0.10. High VIF values (VIF = 1/TOL), also indicate a high degree of multicollinearity, and the rule of thumb is the VIF should be

Table 4: *Multicollinearity Statistics*

Model	Collinearity Statistics	
	Tolerance	VIF
(Constant)		
CMMI II	.377	2.651
SCMMI III	.265	3.778
CMMI IV	.277	3.608

Source: *Survey Data*

less than 10 (Hair et al. 2014). Table 4 illustrates the Multicollinearity variables, and all are at the acceptable range.

Regression Analysis

Regression analysis was performed in order to establish the relationship between CMMI levels and project performance. As illustrated in Table 5, "R" is approximately 0.721, signifying a notably positive linear relationship between CMMI levels and PM. Moreover, R2 and adjusted R2 values are 0.519 and 0.501 respectively. Hence, it is concluded that roughly 51.9% of the fluctuations in the PM can be elucidated by the CMMI levels.

Table 5: *Model Summary*

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.721[a]	.519	.501	8.89911

a. Predictors: (Constant), SUM_CMMI_IV, SUM_CMMI_II, SUM_CMMI_III

Source: *Survey Data*

The ANOVA substantiates the statistical significance of the comprehensive regression model ($p < 0.05$). The F-statistic serves as a measure of the model's goodness of fit to the data. As indicated in Table 6, the F statistic (28.097) ensures the fitness of the model.

Table 6: *ANOVA*

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	6675.447	3	2225.149	28.097	.000[b]
	Residual	6177.150	78	79.194		
	Total	12852.598	81			

a. Dependent Variable: PP_SUM_FINAL

b. Predictors: (Constant), SUM_CMMI_IV, SUM_CMMI_II, SUM_CMMI_III

Source: *Survey Data*

The Beta coefficients express how many units of project performance increase for a single unit increase in each predictor as indicated in Table 7. Beta coefficients of predictor variable CMMI III stands for, 0.583, and t-statistic stands at 3.143, with a corresponding p-value ($p < 0.05$) inferred that CMMI III likely exerts a statistically significant and positive influence on project performance.

Conversely, the Beta coefficients of CMMI II and CMMI IV are notably lower at 0.299 and 0.126 respectively and have relatively high p-values ($p > 0.05$). These results collectively suggest that CMMI II and CMMI IV lack a statistically significant impact on project performance.

Table 7: *Coefficients*

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.042	5.446		.742	.460
	SUM_CMMI_II	.299	.196	.195	1.525	.131
	SUM_CMMI_III	.583	.186	.480	3.143	.002
	SUM_CMMI_IV	.126	.203	.092	.620	537

a. Dependent Variable: PP_SUM_FINAL
Source: *Survey Data*

Based on the scores of predictors, project performance can be calculated as;

Project performance = 4.042 + (0.299 x CMMI_II) + (0.583 x CMMI_III) + (0.126 x CMMI_IV)

One-way ANOVA Test
One of the steps in the One-way ANOVA test is to test the assumption of homogeneity of variance, and since the F value (34.862) is significant ($p < 0.05$), which indicates that at least one pair of means differ significantly as illustrated in Table 8. Hence, it is concluded that there is a difference between means that exist, and it is required to conduct post-hoc analysis for multiple comparison to identify which specific means are different.

Table 8: *One–way ANOVA*

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	6025.511	2	3012.756	34.862	.000
Within Groups	6827.086	79	86.419		
Total	12852.598	81			

Source: *Survey Data*

The Levene's F Test for Equality of Variances is the most commonly used statistic used to test the assumption of homogeneity of variance. As shown in Table 9, the F value for Levene's test at 1.983 with a significant value greater than 0.05 ($p > .05$) indicates that there is no difference for the assumption of homogeneity of variance and concludes that there is not a significant difference between the three group's variances (CMMI levels of projects). Therefore, the assumption of homogeneity of variance is met.

Post-Hoc Test (Multiple Comparisons)
Tukey's HSD (Honestly Significant Difference) procedure allows the comparison of all pairs of means. If the assumption of homogeneity of variance has been met (Equal Variances Assumed,) the most commonly used test is the Tukey (HSD) test. The results of the Tukey HSD

Table 9: *Test of Homogeneity of Variances*

Levene Statistic	df1	df2	Sig.
1.983	2	79	.145

Source: *Survey Data*

test which is indicated in Table 10 shows that there is a significant difference between CMMI level II and CMMI level III, as well as CMMA level II and CMMA level IV, and also CMMA level III, and CMMA level IV with project performance where all pairs of means show significant ($p< 0.05$).

Table 10: *Multiple Comparison Tukey HSD*

(I) Cluster Number of Case	(J) Cluster Number of Case	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-12.98559*	2.45681	.000	-18.8541	-7.1171
	3	-24.17943*	2.91144	.000	-31.1339	-17.2249
2	1	12.98559*	2.45681	.000	7.1171	18.8541
	3	-11.19384*	2.57995	.000	-17.3565	-5.0312
3	1	24.17943*	2.91144	.000	17.2249	31.1339
	2	11.19384*	2.57995	.000	5.0312	17.3565

Dependent Variable: PP_SUM_FINAL

*. The mean difference is significant at the 0.05 level.

Source: *Survey Data*

As the study hypothesized those organizations at different levels of CMMI (CMMI II, CMMI III, and CMMI IV) exhibit different levels of project performance in IT projects, it can be accepted.

CONCLUSION AND DISCUSSION

Results indicate the CMMI level III has higher statistically positive influence on project performance than CMMI level II and CMMI level IV which implies that software projects are properly managed including the software process for both management and engineering activities, and also these are documented, standardized, and integrated into a standard software process for the entire organization. These results collectively suggest that CMMI level II and CMMI level IV lack a statistically significant impact on project performance. This outcome implies that even though software development organization has basic and consistent project management processes to track cost, schedule, and functionality, these organizations further need to strengthen the “Defined” (CMMI level II) stage to improve project performance. Further, at the CMMI level IV as “Quantitatively managed” needs more improvement such as set quantitative goals for software process and software maintenance as well as the processes of performance needs to be controlled using statistical and other quantitative techniques. This study concludes that CMMI levels do have different impacts on software project performance and somewhat contradictory to previous study by Gunasena, (2016) which suggested that higher CMMI levels are highly associated with improving software project performance. Moreover, findings of the present study is harmonious with some other previous studies such as CMMI Level-III informally, SMEs with more than five years of their establishment has suggested a positive move towards maturity with CMMI Level III (Singh & Gill, 2020), CMMI has a significant positive change on organizational performance (Padma et al., 2008), implementing CMMI levels improve customer satisfaction and software quality (Abu-Baker et al., 2019). Moreover, most of the organizations have been adopted standard project management methodologies.

In terms of contributions to practice, this study provides insights into the key stakeholders of the software project management organizations in Sri Lanka such as project managers, business analysts, developers, designers, customers, users, and external consultants on the importance of adopting CMMI levels.

Limitations and Future Research

This research was conducted based on software development companies in western province of Sri Lanka. Therefore research has limitations to generalize the results. Also, project performance was measured by considering six constructs that can be found in the literature. Many factors affect project success from different points of view such as project managers, clients, software developers, users, etc. Another limitation is that this research mainly focused only CMMI level as software process improvement methodology. But other methodologies like ISO (International Standards Organization) quality certificate, Six Sigma, and Total Quality management could be also considered for empirical research. The current study is based on software developers and the target sample is software developers in the western province. If anyone is capable enough to get the target sample island-wide, it helps to identify why most of the software development companies are centralized in the Colombo area and that will be a most important fact in the Sri Lankan software industry.

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