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Integration of Project Management Maturity (PMM) Based on Capability Maturity Model Integration (CMMI)

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Abstract

Software development is an industry sector which is typified by rapid change and iterative progress. In consequence a number of project management frameworks exist within the field of software development. Some of these have been developed from existing models taken from other industry sectors and some have emerged over time in response to the rapidly changing needs of software developers and their supporting project teams. This research specifically examined two particular frameworks which are popularly used within software development, the Project Management Maturity (PMM) framework and the Capability Maturity Model Integration (CMMI) framework. This research critically compares and contrasts the two and proposes a synthesized framework which draws upon the best elements of both of these models to create an agile framework which encourages best practice and technical precision within software projects. It is determined that a synthesized framework reduces the risks inherent in project management and can be effectively deployed in a range of situations.

Keywords: Project Management; Software Projects; PMMI; CMMI

1. Introduction

The Project Management Institute (PMI) was founded in the 1970's with the aim of creating a cohesive body of knowledge relating to professional project management 427[40]. Over time the PMI has come to be regarded as one of the leading authorities on best practice in project management, and at the time of writing the Project Management Body of Knowledge PMBOK as published by the PMI has come is considered to be one of the leading authorities on best practice in project management. It is asserted by [10] that adherence to this model provides the fundamental framework for project management success. There are, however, other professional bodies which also devote themselves to the school of thought pertaining to successful project management. In the late 1980's the US Department of defense (DoD) sponsored work at Carnegie Mellon University focusing on software engineering as an emerging discipline [44]. Collaboratively they developed a tool known as the Capability Maturity Model (CMM) which facilitates baseline assessment of organizational performance within software or IT organizations. Over time it has come to be regarded as the *de facto* standard within the industry. In 2000 the model was renamed the Capability Maturity Model Integration (CMMI) on the basis that a very large proportion of the work conducted by software and IT organizations relates to the implementation of new or upgraded systems, and this requires a distinct form of project management. It is asserted by [35] that over the last decade, the CMMI has come to be regarded as the benchmark standard tool for this process. The aim of this study is to bring together these two aspects and to identify how they can be integrated to form one unified tool which can be applied in a wider range of software project management situations. Currently, there remains alarmingly high number of software project failures, with the term "failure" being used as an umbrella term to cover a range of distinct issues [31]. It is posited that use of a hybrid tool drawing upon best practice from the PMBOK and the CMMI will create an all-embracing framework which will allow organizations to identify potential issues before they become problems, thereby averting project management failure in a software context. Moreover it is hoped that the use of an integrated framework will increase the efficacy of project management and will allow the stakeholders involved to have greater control and visibility of any potential issues. This paper is organized as follows section 2 will provides critical discussion of the relevant literature and empirical evidence; section 3 sets out the research methods and justifies it; section 4 develops the synthesized conceptual framework and critically considers the anticipated benefits and likely challenges; finally section 5 will presents conclusion and recommendations and will identifies areas for further research.

2. Literature Review

This section presents a critical analysis of existing literature relating to project management in a software environment, the PMM and the CMMI. It also considers the benefits and challenges associated with project management, the use of these conceptual frameworks, and the likely implications of synthesis in a software environment and in the wider body of knowledge relating to project management in general. According to [10] at its most basic level project management can be defined as:

> *"The discipline of planning, organizing, motivating, and controlling resources to achieve specific goals"*

This view is shared by the PMBOK[37], who expand upon this definition and suggest that because projects by their very nature are discrete endeavors with a defined timescale, there is a need to acknowledge the constraints of time as part of the definition of project management. Further to this[34] suggests that good project management is concerned with the introduction or demonstration of value in exchange for resource and effort, and therefore these should also be acknowledged in the definition of best practice in project management. He suggests that this could potentially take the form of benchmarking or retrospective assessment and evaluation to determine the extent to which a project has achieved its objectives. Further to these discussions [7] suggest that within the software sector, it is necessary to acknowledge the idiosyncrasies of this industry, and therefore definitions of project management should incorporate the specifics relating to software project management. To this effect the *Systems Development Life-Cycle* (SDLC) is defined as:

> *"The process of developing information systems through investigation, analysis, design, implementation and maintenance"* [33].

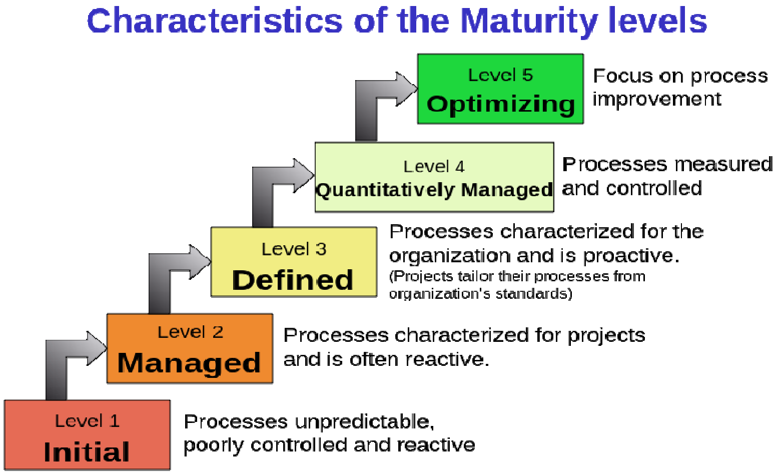
According to [39], the SDLC represents a distinct niche of project management which is concerned with the tools and techniques associated with software development and project management, including *inter alia*, agile methodologies, the waterfall method, prototyping and incremental development. The Project Management Institute [40] has proposed the following definition of project management maturity (PMM):

> *"Organizational Project Management Maturity describes an organization's overall ability to select and manage projects in a way that supports its strategic goals"*

It is acknowledged in practitioner discussions and literature that the PMM approach is resource intensive and is also reliant upon the project team or the project manager having considerable expertise within a particular area in order to facilitate effective project management [27]. Furthermore there is acceptance of the fact that in order to overcome the known challenges of project management, particularly issues such as increased risk [47] and problems with "scope creep" [10][2], it is imperative to maintain tight control of the project and to respond rapidly to any potential problems which may cause the project to miss objectives or targets. Further to this, [30] assert that application of the PMM delivers several benefits including (i) the ability to articulate project success in a manner that external stakeholders can appreciate; (ii) the ability to objectively measure project performance against targeted aims; (iii) increase the predictability of project delivery and the accuracy of project timescales and costs; and (iv) encourage internal communication in a multi-project environment to increase the effectiveness of resources, and potentially contract the overall timescale without adversely impacting on quality. For these reasons the PMM has come to be acknowledged within the software industry as a comprehensive and versatile conceptual framework which can be applied in a range of circumstances [32]. In its most direct form the capability maturity model (CMM) is a framework which helps organizations to increase process efficiency across a range of business operations [13]. The CMM framework was first presented by[36] at Carnegie Mellon University in response to evolution in software development and project management. The framework has subsequently been adopted in other industry sectors to illustrate how improvements in business processes can significantly increase organizational efficiency [38]. The CMM shares aspects of best practice project management and lean techniques to facilitate an iterative approach the process improvement which results in increased efficiency and effectiveness[11]. Holcombe [24] explains that under this approach business processes are rated or measured according to their level of maturity using the following five benchmarks and figure-1 below provides a visual illustration of how these five stages build upon one another.

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

Figure-1: *Characteristics of Maturity Levels within CMM (Source:[36])*


Characteristics of the Maturity levels
Level 5
Optimizing
Focus on process improvement
Level 4
Quantitatively Managed
Processes measured and controlled
Level 3
Defined
Processes characterized for the organization and is proactive.
(Projects tailor their processes from organization's standards)
Level 2
Managed
Processes characterized for projects and is often reactive.
Level 1
Initial
Processes unpredictable, poorly controlled and reactive

Englund and Graham [20] explain that the CMM was originally developed to synthesize a number of different benchmark approaches and conceptual frameworks within the field of software development in order to provide a cohesive framework in the industry which could be used on an international basis. The fundamental aim of the CMM is to help an organization align all of its business processes to achieve and support overall organizational objectives. Gardiner [22] expands that the CMM has been superseded by V1.2 known as the *Capability Maturity Model Integration* (CMMI) which looks at best practice when integrating and implementing new business processes on a cross organizational basis. Obvious examples include the use of systems to transfer data between organizations on a real-time basis in order to improve organizational efficiency. According to [45] the CMMI has two forms of operation; (i) continuous; and (ii) staged or incremental. As these terms suggest, continuous application refers the development and maintenance of the status quo and incremental refers to the ongoing development and process improvement to deliver organizational efficiency. Further to this[35] explains that the CMMI operates in three fundamental areas (i) acquisition; (ii) services; and (iii) development. This is because these three areas essentially describe overall business operations at generic level. From a practical perspective organizations are appraised as to their maturity level and a score is awarded. Effectively this benchmarks the organization and they can use this knowledge to improve their process maturity and thus by extension the efficiency and integration effectiveness [48]. Further to this it is suggested by [25] that the linkage between CMMI and lean helps to transfer best practice knowledge the other industry sectors outside of software development. The main challenges with using the CMMI relate to the very rigid approach to process control which can in some instances be overly oppressive, especially in agile project development [3] or small-scale operations [6].

2.1. Challenges in Project Management

According to [29] all projects are at risk of project failure, although the root causes of project failure are varied and in some cases difficult to control. Considerable literature and research has been devoted to identifying consistent themes in project management failure such that they can be isolated and rectified before they become an issue. Overall it is suggested by [34] that the most common themes of project failure and challenge can be summarized as follows:

- Poor definition of project management requirements, including issues such as scope, resource requirements, and budget availability
- Failure to manage the expectations of stakeholders involved in a project, both internally and externally, leading to unrealistic demands and ineffective resource management.
- Difficulties in communication, especially in international projects as a result of flawed fundamental assumptions as the expectations and requirements
- Weak project management as a result of a lack of structural framework and/or a lack of project management experience
- Failure to respond effectively to external factors influences which have the potential to derail a project, including problems with external suppliers or extrinsic variables beyond the control of any of the stakeholders

According to [34] any one of these challenges has the potential to cause project failure, and this is why the application of either the PMM or the CMMI can significantly reduce the risks associated with project management, and enhance the effectiveness and efficiency of the project.

2.2. Synthesis of Frameworks

There is an emergent body of knowledge which advocates the synthesized use of recognized software development frameworks such as Extreme Programming [46], Agile [28], Scrum [19] and even classical techniques such as the waterfall method [26] . Krzanik *et al.* [28] go further than this and suggest that it is time for an entirely new perspective which is not solution driven but value driven and encourages developers to identify sources of value before establishing which aspects and techniques of project management would be required. They also assert that it is necessary to consider wider or multiple perspectives when planning and preparing for project development to ensure that a project is accurately scoped. Both[28] and [42] believe that despite significant advances in software and project management techniques, a failure to communicate effectively at the outset and scope projects accurately remains as one of the greatest inhibitors of project management success. It is evident from the literature that there is a clear desire within the software community to be as proactive and effective as possible when developing software. However it is also suggested that the perennial problem of poor communication between project management stakeholders remains one of the greatest challenges to project management success. There is also some concern as to the blending of established software development frameworks such that maximum utility is obtained as opposed to suboptimal performance through rigid application of established frameworks. As the overarching aim of this study is to bring together two well-established software development frameworks in the synthesized fashion it will be necessary to consider the benefits and challenges in quite considerable depth.

3. Research Method

This section describes and justifies the research methodology applied in this study. According to [1] research studies such as this which blend empirical findings and theoretical considerations in attempts to develop a new conceptual framework are firmly rooted in the sociological school of thought. As such there are a number of alternative research methods and supporting approaches, which could be adopted to achieve the overall research aim. Therefore, this section critically contrasts the schools of thought as regarding research philosophies and approaches, and also the detail of the research strategy and data collection. Christensen *et al.* [14] explain that positivist research typically engages the use of hypotheses which are then proved or disproved as a result of the empirical study. At the opposite end of the spectrum [15] describe the research philosophy known as interpretivism, which they explain is typically focused on understanding the perspectives of research participants or stakeholders within a certain subsection of society. It is normal in interpretivist research to focus on the context of the study and the responses of the research participants to their contextual understanding, as this can help to describe and explain their behaviors. For example, within the context of this study using an interpretivist approach and gathering primary data which explains why project management stakeholders adhere to or deviate from accepted best practice techniques might help to explain why a new synthesized approach to project management is relevant.

Further to this,[43] point out that it is necessary to explain where the data was acquired from in order to justify its inclusion. Accordingly, data for this research study was gathered from reputable and reliable sources including academic and practitioner journals and literature, presentations from conferences and to a limited extent the website of relevant professional bodies including the Project Management Institute (PMI)[40] and the Software Engineering Institute (SEI)[44]. Given that this study is seeking to explore contemporary and forward facing aspects of software development it is necessary to rely upon recent data which challenges and critically assesses current thinking [50]. There will however be inclusion of recommended best practice in classical thinking to provide a foundation and a comparator for the proposed conceptual framework. For these reasons the search terms identified during the data collection process included the following:

- Project management maturity (PMM)
- Capability Maturity Model Integration (CMMI)
- Agile Software management
- Project Management
- Extreme programming
- Scrum management

Preference was also given to empirical research studies which demonstrated the efficacy or otherwise of these approaches using case studies and primary evidence [43]. This was deliberate in order to ensure that sufficient proof was presented of the likely capability of the synthesized framework. Under the principles of grounded theory, data analysis took place using a four stage process of coding, cross assessment, conceptualization and development of theory, in this case the presentation of an augmented and synthesized project management framework. As the aim of this study was to present a new approach bringing together the best elements of the PMM and the CMMI, this required detailed consideration of the respective merits and challenges as elucidated it by previous academics such as[28] and [42]. According to [12] this is in fact a normal element of grounded theory which has inherent risk of failing to deliver any innovative outcome. However despite these setbacks it was possible to present a new framework as will be shown in the following section.

5. Findings, Analysis and Critical Discussion

As the aim of this research is to develop future best practice in software project management it seemed prudent to critically assess contemporary recommendations as regards best practice in this area. Further to this there was a need to consider potential "future proofing" of software project management in light of external considerations such as the development of disruptive technology and shifting social perceptions needing to differing stakeholder requirements and expectations [19] [8]. In light of the discussions of academics such as [28] and [42] it is clear that there are a number of issues to consider in the development of the synthesized framework, not least of which is the inclusion of multiple stakeholder perspectives and acknowledgement of the need for increased flexibility in the interpretation of framework requirements. Therefore, the research in this area focused on the benefits of synthesis and also the challenges highlighting the fact that whilst synthesized frameworks are welcomed within the software development and project management community, there is justifiable reticence in some specific areas. This helps in the development of the new conceptual framework as identification of known weaknesses can be specifically targeted and overcome with the development of a new model. This can arguably be regarded as an innovative contribution to the body of knowledge in this area. There is much in the way of best practice recommendation for successful project management. It is accepted in academic research that there are trends in best practice as fresh evidence is discovered and external circumstances change [5]. However, software development appears to possess a specific idiosyncrasy in that acknowledged best practice changes at an accelerated pace [41] [4], which is almost inevitably a consequence of the speed of development in this field.

5.1. Benefits of Synthesis

It is interesting to observe that current practitioner thinking already focuses on a synthesized form of the PMM and CMMI, as evidenced by the technical detail in some aspects of current thinking which is more closely aligned with the CMMI, and yet acknowledges the need to interface effectively with all stakeholders which is characteristic of the PMM. It is suggested that the following benefits can be accrued:

Reduced overall cost: This is quite significant as cost is accrued from multiple stakeholder perspectives. These include the time necessary to manage the project end to end, reduced client expenditure because of single license requirements, use of stable and proven coding under UML and OO best practice which reduces the time spent in testing and any risk of instability, and increased efficiency because of the contracted SDLC.

Simplified Interface: Although from a technical perspective relatively little time is actually expended on the UI because the vast majority of work relates to architecture and coding, the UI is still the most important aspect for end users because this is what they will focus upon. Creating a simplified interface because of a synthesized process which wherever possible utilizes existing knowledge and work will help to improve the perception of success on about the client, increasing efficiency and reduce risk. Moreover by focusing on the interface at an earlier stage in the life-cycle process (refer back to the discussions on recommended best practice) it is possible to reshape the architecture and coding in alignment with user needs.

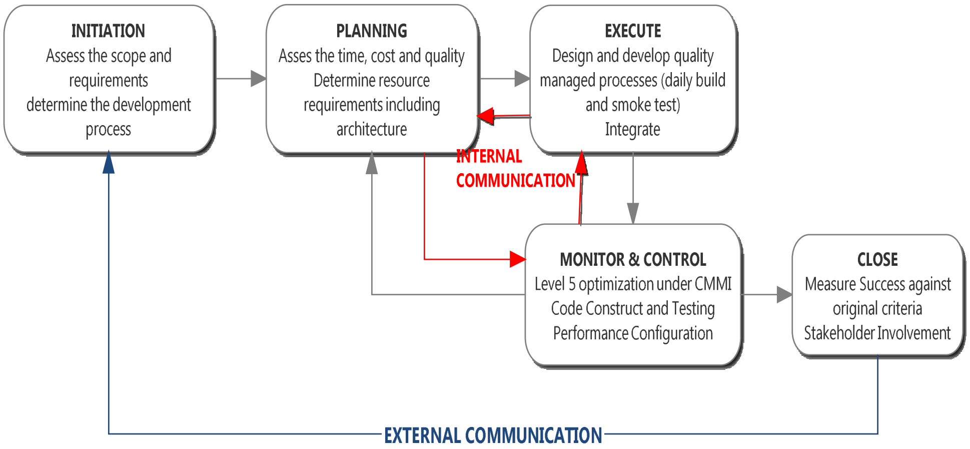
Reduced risk: This is because the technical and human aspects of project management and software development are combined and aligned, which reduces the risk of issues such as scope creep and the need to retrospectively review or assess a project. Reduced risk typically leads to reduce costs and a closer link between the development companies and the end user and client stakeholder also build a stronger long-lasting relationship. It should be recalled that for many pieces of bespoke software purchased by clients there is an expectation of a 5 to 10 year life-cycle of the software *in situ* [18] and therefore it is important that there is a good relationship between the software provider and the client stakeholder.

5.2. Likely Challenges of Synthesis

It is suggested that there are relatively few potential challenges which may arise from synthesizing the two frameworks. Fundamentally because contemporary evidence from practitioners would suggest that they have already begun to adopt a synthesized framework which blends the best aspects of both of these models. Moreover it is noted that for best practice it is necessary at the outset of a project to determine which design framework is best suited, and also that successful deployment of the design framework is far more effective and important than arguing over the granular detail of whether one model has preference to another. Possible challengers or risks associated with a synthesized model include the fact that some aspects may be inadvertently overlooked; however it is proposed that with a synthesized framework this is a relatively low risk because of the focus on technical accuracy at the outset of the project. The main risks are likely to be associated with obtaining stakeholder buy-in and engagement because of the fact that change is uncomfortable in any project management situation[17]. This is why increased emphasis on the human aspects of project management under the PMM are often more appropriate. There is some concern that technological developments in the wider arena may be inadvertently omitted because of adhering to a defined framework, however with the general trend being a shift towards unified approaches this also seems to be a relatively minor risk which could be retrospectively assessed. One final consideration is the extent to which the first aspects of the project, which are absolutely critical, may be rushed through because they represent relatively little tangible output[49]. However this is a risk for all projects in the planning stages and so once again it is not considered that this is likely to be a major problem or matter of concern.

Thus, having carefully considered the likely benefits and challenges of the synthesized framework and given due consideration to the prevailing lines of thinking amongst practitioners in the contemporary environment the framework shown in figure-2 overleaf represents the suggested amalgamation of the PMM and CMMI. As the figure illustrates, it has been based upon the foundation of the PMM as a proven framework project management in a generic context, however it draws heavily upon the CMMI because this assesses the level of maturity and integration specifically within software projects. Recalling that the key difficulty is the need to balance robust planning and agility in software projects because of their investigative and developmental nature, the key to flexibility is internal and external communication. This is represented by the red lines shown in the diagram which illustrate the need to have reciprocal communication on an internal and external basis facilitating the flexibility required for project of this nature.

Figure-2: Proposed Synthesized Framework


INITIATION
Assess the scope and requirements determine the development process
PLANNING
Asses the time, cost and quality Determine resource requirements including architecture
EXECUTE
Design and develop quality managed processes (daily build and smoke test) Integrate
INTERNAL COMMUNICATION
MONITOR & CONTROL
Level 5 optimization under CMMI Code Construct and Testing Performance Configuration
CLOSE
Measure Success against original criteria Stakeholder Involvement
EXTERNAL COMMUNICATION

6. Conclusions and Future Work

To re-cap, the principal aim of this research was to critically assess the literature relating to best practice in project management software environment, and then to synthesize the PMM and CMMI to develop a conceptual framework which is fit for purpose in the contemporary business environment. This involves three principle objectives, *viz*, (i) a critical assessment of the PMM; (ii) a critical assessment of the CMMI; and (iii) creation of a synthesized framework based on contemporary discussions and current best practice to support future developments from multiple stakeholder perspectives. Particular consideration was given to the realities of best practice in project management at the time of writing, taking into account the fact that software development is a particularly fast moving environment because of the perpetual innovations in technology and increased demands of stakeholders. The literature review and the practical evidence made it clear that in reality many developers are working under particularly significant pressure to complete projects in a short space of time in order to manage stakeholder expectations, and relatively few have the luxury of being able to use more sophisticated development techniques which cannot be justified in the face of time and cost pressures[21].

In conclusion it was established that a synthesized framework would attract relatively low risk in comparison to the benefits that it would accrue. Moreover software developers themselves are keen to create iterative cycle testing within the life-cycle the project to reduce risk and unnecessary expenditure, however sometimes necessary to enforce discipline to achieve this[17]. Therefore the use of a synthesized framework which can function in a global remit because of the use of UML is considered to be of value. Finally, because the synthesized framework shown at the close of section 4 has scope for increased granularity as necessary this recognizes the fact that the key to successful project management is not automatically a focus on technical detail at the outset, but rather successful execution and that blending the two approaches should provide a robust outcome. Moreover, the fact that the synthesized framework attracts relatively little risk is a peripheral bonus and not necessarily a key driving factor. Moreover it should be emphasized that there is nothing to stop use of the synthesized framework at an initial level with subsequent incorporation of specific elements of existing models should further granular detail be required. Therefore, it is recommended that the synthesized framework is adopted wherever possible however there should be acknowledgement of the fact that it can be adapted as required for the specifics of any project. The only factors which may not be subject to compromise are commitment to technical excellence and project execution, and ensuring that stakeholders are engaged. Therefore this is the other key recommendation when deploying this framework. Other than that the project framework itself is wholly self-explanatory and as it rests upon proven project framework approaches there is little need to reiterate its use. In closing it is considered that this framework can be adopted with immediate effect, and will doubtless benefit from the input and interactions of experienced practitioners and academics in the field.

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