

DESIGN OF A KNOWLEDGE MANAGEMENT AND ORGANIZATIONAL
LEARNING SYSTEM FOR IT PROJECT PORTFOLIO MANAGEMENT

by

Itay M. Erhard
Columbia University

2012

ABSTRACT

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IT Project Portfolio Management (PPM) has become a critical practice in information intensive organizations and an important sub-field of academic Information Systems (IS) research in recent years. Nevertheless, only a small minority of the organizations that had attempted to adopt PPM appears to be realizing its full potential (Jeffrey & Leliveld, 2004). The basis postulate of this study is that lack of effective Knowledge Management (KM) processes for PPM is a pivotal contributing factor to this disparity between expected and actual value realization.

Hence, a high-level design of a Knowledge Management System (KMS) for PPM is proposed, based on an independent study and input from field practitioners (N=40), supported by concepts from the Situated Learning Theory (Lave & Wenger, 1991). It is the aim of this study to carve the way for detailed designs and system development of this concept, ultimately resulting in working systems that would foster Organizational Learning (OL) and improved results for PPM adopted organizations.

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I--BACKGROUND

Overview

The concept of Portfolio Management was introduced by the Noble laureate Harry Markowitz in 1952, who laid down the basis for the Modern Portfolio Theory (MPT). The MPT proposed methods for determining the specific mix of investments given expected return and risk tolerance. Although MPT was initially developed by Markowitz specifically for financial investments, such as securities, Warren McFarlan (1981) has demonstrated nearly three decades later, how some of the MPT concepts could be applied to IT projects, providing the basis for modern IT Project Portfolio Management (PPM).

McFarlan suggested that the general poor performance of Information Systems (IS) projects is associated with three main deficiencies in management practices: failures to properly assess the risk of individual projects or the aggregate risk of project portfolios, and failure to apply adjusted managerial approaches to different projects based on their nature. McFarlan therefore recommended that management employs a consistent and well thought out risk-based approach to the selection and management of IT projects, as well as calculating and controlling the aggregate risk profile for the IS portfolio as a whole.

Since then, PPM has become a critical practice in information intensive organizations and an important sub-field of academic Information Systems research. For example, Jeffery & Leliveld (2004) reported on interviews of 130 Chief Information Officers of Fortune 1000 companies about their organizations' adoption of PPM; the results showed that 89% of the CIO's were very aware of PPM and 65% believed that the approach yields significant business value. Nevertheless, out of the organizations participated in Leliveld's study, only a small minority (17%) that had attempted to adopt PPM appeared to be realizing PPM's full potential, based on their failure to implement key PPM elements.

The basic postulate of this study is that fundamental attributes of PPM implementations make organizational PPM KM a pivotal factor in successful adoption of PPM processes, yet one that has not been thoroughly studied. As such, it serves as a critical contributing factor to this disparity between its expected and actual value realization. This postulate has led to initiation of scholarly work that began with a literature review (Erhard, 2009), followed by a subsequent study “Knowledge Management Solution for IT Portfolio Management: Definitions and Design Considerations” (Erhard, 2010), both of which leading to the present study.

This scholarly work is primarily aimed at validating the aforementioned postulate and proposing a technological approach for minimization of the identified gap, which is the primary purpose of the present study. The specific contributions of these two papers to the present study work shall now be briefly described.

The literature review included an assessment of scholarship in areas that have an implication for the present study, including historical overview, research trends, research focus areas, open research questions, and scholarly debates; validated the existence of a gap in the literature and the industry that this study purports to address, characterized it, and confirmed the importance of addressing it; examined and validated the capability of the chosen instrument, Knowledge Management System (KMS), to effectively address the identified gap; identified, validated, and enhanced the understanding of the theoretical foundations behind the proposed solution framework; and stimulated thoughts about specific research questions as well as possible research methods to be employed as part of the present study.

The subsequent study further advanced the preparations for the present study by taking the first step in the development of the solution framework. First, different perspectives of relevant terms have been discussed and certain views that are essential to the present study adopted. Second, an initial list of design considerations of the eventual KMS has been formed and discussed.

The *situated learning theory* (Lave & Wenger, 1991) was selected as the primary learning theory to support this study, chiefly due the strong demonstrated applicability of its key principles to KM and OL in general (e.g. Wenger, 1998). The first key principle of the theory is the concept of Communities of Practice (COP), which are groups of people

who engage in a process of collective learning and interact regularly, whether intentionally or incidentally. The second key principle of the situated learning theory is that learning is "situated", as it takes place in the same context in which it is applied, and is a function of the activity and culture in which it occurs. This view contrasts most classroom learning activities that tend to expose students to abstract and out-of-context knowledge. Along those lines, the intent of the KMS design is to facilitate learning through the use of technological capabilities that facilitate contextual knowledge acquisition, and learning among COP members.

Definitions and Focus of Work

Overview

This section discusses and adopts definitions and views of key relevant terms heavily used throughout this study. Definitions of terms such as "knowledge" vary so much on one hand, and have such strong implications for the KMS design on the other hand, that their clear definition is a necessary prerequisite for the remainder on this study.

Views of Knowledge and Implications for Knowledge Management

The most popular approach for defining the term "knowledge" appears to be through distinctions among the terms data, information, and knowledge while articulating the relationships among them. Such distinctions are of particular importance from an IS perspective, as the assumption is that if knowledge is not different than data or information, then there is nothing new or interesting about KM from an IS perspective (Fahey & Prusak 1998).

For example, Davenport and Prusak (1998) defined the term data as "A set of discrete, objective facts about events" (p. 2) while drawing on Drucker's view (1988) that information is "data endowed with relevance and purpose" (p. 124). Their view implies

that data by itself has little relevance or purpose, yet is highly important to organizations as it forms the basis for creation of the higher impact entities, information and knowledge. The endowment of "relevant and purpose" to data is performed by humans who analyze the data and transform it to information through techniques such as data manipulation and representation, which are normally enabled through IS. Davenport and Prusak defined the following list of typical methods that are employed to transform data to information: contextualization, categorization, calculation, correction, and condensation. They further view information as a "message, usually in the form of a document or an audible or visible communication... it has a sender and a receiver... expected to change his [receiver] perception and has an impact on his judgment and behavior" (p. 3).

The above definitions of the terms data and information are believed to be more relevant to IS work than other widely-cited definitions in the literature (e.g. Nonaka & Takeuchi, 1995; Spek & Spijkervet, 1997), which their applicability to IS is less intuitive, and will therefore be adopted. The only exception is Davenport and Prusak's view of information as a message, which may not adequately consider or explain contemporary IS methods used by organizations. For example, sophisticated reporting tools, such as enterprise portals, may be configured to automatically apply data-to-information transformation methods to organizational data and present it through reports. This would sometimes apply relevance and purpose to the data in question, yet without necessarily transmitting any messages or perhaps without any human consumption of it at all.

While the term "knowledge" is more elusive than the terms "data" and "information" and has been accorded more attention in the literature, there seems to be a consensus that knowledge is deeper, broader, richer, and more powerful than the first two (e.g. Nonaka & Takeuchi, 1995; Davenport and Prusak, 1998). In order to transform information to knowledge, humans apply cognitive techniques (Davenport & Prusak, 1998) such as comparison (e.g. "What can be learned from comparing two pieces of information that relate to the same data?"), consequences (e.g. "What are the implications of the information?"), and connections (e.g. "How does the information relate to other pieces of knowledge or information?").

Out of a large number of widely cited definitions of this term, Wiig's (1993) definition of knowledge as "...truths and beliefs, perspectives and concepts, judgments and expectations, methodologies and know-how" (p. 73) is believed to best align with the aim of this study, and easy to comprehend at the same time. The only problematic element of Wiig's definition is believed to be its reference to "truths", a highly controversial and subjective term. Therefore, Wiig's definition shall be adopted for this study with the exception of its first element.

Alavi and Leidner (2001) summarized the different perspectives applied to knowledge by KM and IS researchers, each of which has implications for both KM and KMS. Out of the five perspectives reviewed in their study (knowledge as an object, a process, a capability, state of mind, or a condition of having access to information) the first three will be adopted in this study and briefly described.

The view of knowledge as an *object* that can be stored and manipulated is held by some scholars (e.g. McQueen, 1998; Zack 1998a) and most consulting firms in the industry, who use it to apply their expertise and train junior consultants (e.g. KPMG Management Consulting, 1998). This view of knowledge leads its holders to believe that the key focus of KM should be on building and managing knowledge stocks, by using KMS's capabilities of storing, transferring, and presenting knowledge. For example, as it is often difficult to convert tacit knowledge held in the minds of experts to explicit knowledge, a popular solution involves capture of electronic message based discussions related to knowledge domains organized by contextual data (McQueen, 1998).

The second view of knowledge that will be adopted in this study as the *process* of applying expertise, such as employing a certain technique for fixing a device, or interviewing a job candidate. This view of knowledge dictates a KM focus on processes for creating, sharing and distributing knowledge. Respectively, the role of IT as viewed by holders of this view (e.g. Zack, 1998a) is to provide links among sources of knowledge in order to improve knowledge flows.

The third view of knowledge defines it as a *capability* with the potential to influence action. Holders of this view (e.g. Carlsson et al., 1996) believe that KM efforts

should focus on building core competencies and the role of IT is to enhance intellectual capital by supporting the development of individual and organizational competencies.

Holders of the fourth view of knowledge, as a *state of mind*, believe that the role of IT is to provide access to sources of knowledge rather than knowledge itself (e.g. Schubert et al., 1998). This view will not be adopted as it is believed that it does not reflect the capabilities of contemporary IS methods which sometimes *do* provide the means of producing knowledge through techniques such as data mining.

Similarly, it is believed that the fifth view of knowledge, as a *condition of access to information* (e.g. McQueen, 1998), which views the role of IT as a provider of search and retrieval capabilities, belittles the capabilities of contemporary IT methods and will not be adopted either.

Knowledge Management Strategies and Knowledge Management Technologies

A fairly recent study by Saito, Umemoto and Ikeda (2007) has been used as a guideline for determining certain elements of specific KM solutions and several of its key definitions. Their study is a convenient tool for this purpose, as it describes the relations among technology, KM and strategy, and categorizes available KM technologies according to these relations through an ontological approach.

The authors suggested that the term "knowledge management strategy" most commonly refers to the *approach* taken toward KM, which is reflective of distinct perspectives, conceptualizations, and methodologies that emerge from different backgrounds and interpretations of the terms knowledge and KM. They further suggested that the different approaches to KM could be classified into the following categories: *technology-oriented* approaches, which emphasize the explicit nature of knowledge and its ability to be stored, updated, and transferred through technologies; *people-oriented* approaches, which emphasize tacit knowledge and interpret it as a social, context-dependent process that requires human communication and cognition; *asset-oriented* approaches, which emphasize the economic value of knowledge; and *process-oriented*

approaches, which focus on the increased effectiveness of business processes through provision of context-specific knowledge.

The second meaning of the term "KM strategy" represents *knowledge strategy* and links KM to business strategy. A knowledge strategy identifies unique knowledge that is capable of helping the organization gain major advantages and comprises of two key elements: *knowledge domains*, which are areas of interest that include strategic knowledge resources; and *knowledge intents*, which are knowledge gaps or the difference between existing and required knowledge resources.

The third meaning of the term "KM strategy" represents *KM implementation strategies*. This interpretation, which mainly *applies* to position holders in organizations who own KM programs, focuses on guidelines and expected results from KM initiatives. These guidelines can be classified into three categories: KM pre-conditions, selection of KM initiatives, and establishment of evaluation criteria.

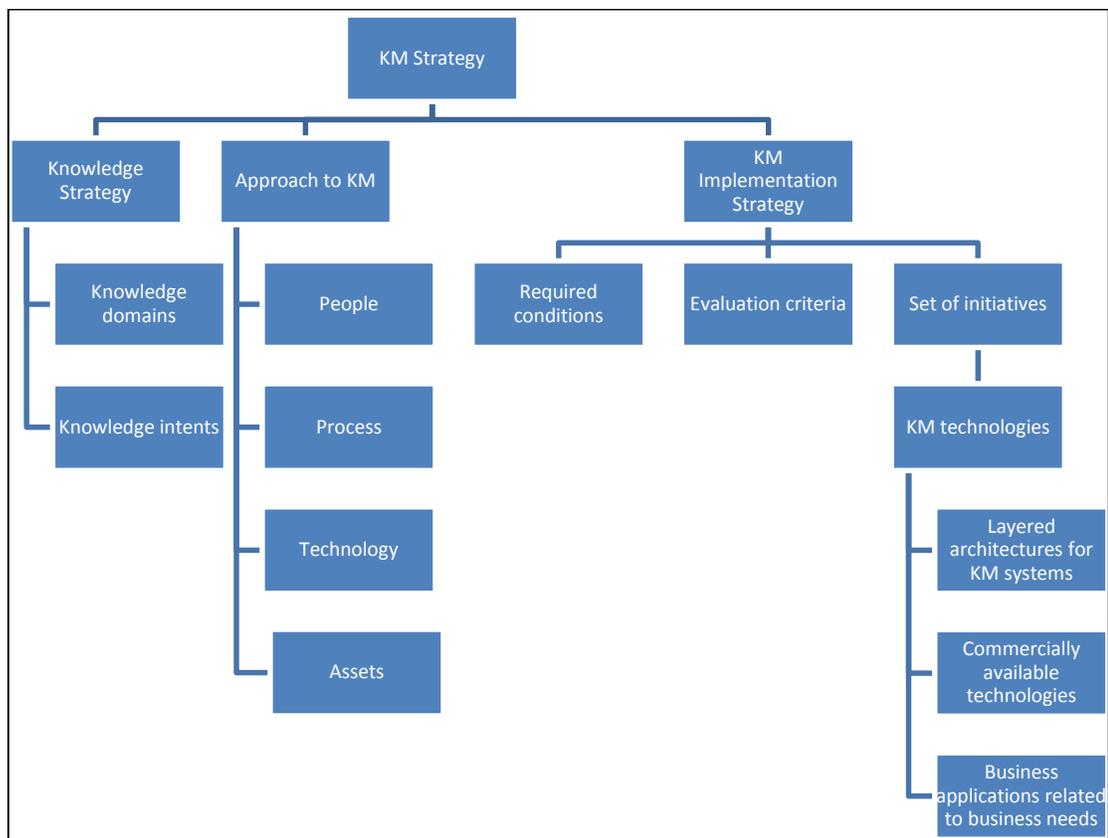
In the present study, the term "KM strategy" refers to a *technology-oriented* approach to KM. Nevertheless, it is clear that as key to the design of an effective KM strategy for PPM, concepts embraced by holders of the second view – KM strategy as a knowledge strategy- will have to be adopted as well. There will be a lower focus on the third view, implementation guidelines, such as cultural and social aspects of it, as it is not primary focus of this study.

The next KM term examined in Saito, Umemoto and Ikeda's study was "Knowledge Management technologies". They suggested that different approaches exist in the literature for describing KM technologies, with the most frequent one being associated with knowledge processes such as knowledge creation, storage, transfer, and application (e.g. Nonaka et al., 2001; Alavi & Tiwana, 2003). Alternate approaches describe KM technologies in terms of commercially available technologies implemented in existing KM initiatives, layered architectures for KM systems required for a complete set of knowledge processes, or business applications related to business needs.

The primary approach for describing KM technologies used in this study, is a *managerial* approach that relates technologies to business needs and focuses on the

function they perform in an organizational context. The adoption of this approach is represented, for example, by the fact that several existing KMS for Project Management (PM), an area that is subsumed by PPM, have been included as a design consideration (e.g. Ayas, 1996). The layered architecture approach to KM technologies has been adopted as a secondary approach, given its emphasis on component technologies, which may be used for a complete set of knowledge processes and activities (e.g. web seminars, reporting), that are expected to be included in potential solutions.

Figure 1. *Conceptual Map of a KM strategy (Saito, Umemoto & Ikeda, 2007)*



IT Project Portfolio Management

While different definitions of the term PPM exist in the literature, Kumar's, Ajjan's, and Niu's (2007) definition has been adopted for the present study, for its completeness compared to other widely cited definitions: "continuous process to manage IT project, application and infrastructure assets and their interdependencies, in order to maximize portfolio benefits, minimize risk and cost, and ensure alignment with organizational strategy over the long run" (p. 2).

Purpose, Scope of Study, and Research Questions

Given the prevalence and significance of the PPM discipline in information intensive organizations on one hand, and its limited value realization on the other hand, there is a growing interest in finding ways of narrowing this gap between its expected and actual outcomes. More specifically, the literature review has demonstrated that this gap is strongly influenced by low to non-existent adoption of KM practices, and it is therefore believed that investigating ways of incorporating KM practices into PPM holds the potential of making a meaningful contribution to the field.

Although the identified gap could be researched from a number of different angles, approaching it from a *technological* perspective was believed to hold a strong potential of resonating well with interested parties and being further developed, for several primary reasons. First, given the strong industry orientation of this discipline, a concrete outcome is likely to be more approachable to the PPM community than more abstract outcomes. Second, the strong penetration of technology into this field, which is only anticipated to strengthen (Gartner, 2010), makes it the primary vehicle by which this discipline manifests itself in organizations. Third, KMS have proven capable of being an effective mean of incorporating KM practices in other domains, as exemplified in the literature review section.

With the identified gap in the PPM discipline, and KMS as the chosen vehicle of approaching it, the next question to answer is the *approach* by which to use this chosen vehicle in this study. While considering what has been learned in the preliminary work of

this study, it was determined that proposition of a *system design* holds the greatest potential of meeting the purposes of this study, for its approachability by a non-technical audience, and for its initial sequence in system development methodologies that is consistent with the current status of this concept.

The term “system design” is broad and subject to multiple interpretations, therefore the next question to answer is its interpretation in this study, as basis for determining its methodology and expected outcomes. Given the non-existence of similar KMS, it was determined that a logical starting point of the design process would be with an *abstract* and *high-level* design which would hopefully lay the foundations for more concrete and detailed design in future studies. In other words, the KMS needs to be designed in a way that would enable the PPM community to determine whether it is worth pursuing further, and if so, provide them with a solid starting point.

More specifically, the eventual solution design covers the following elements: solution capabilities as described from the end users’ perspectives; potential technologies to be utilized in support of the desired capabilities and guidelines for their configuration; abstract solution entities and the relationships among them; design considerations specific to the KMS that should be taken into account during construction; and general system attributes as derived from some of these design considerations. Practitioners and researchers wishing to develop more concrete and detailed design of the KMS will be able to take each of these elements and break it down further while employing conventional system analysis methods and techniques.

As the number of IT initiatives in organizations increases, the value of KM and the risk associated with its absence increase as well. Thus, it was determined that it would be most beneficial to have the KMS design focus on large commercial organizations (>5000 employees) as best fit candidates for its eventual adoption. This decision has manifested itself through focus on design considerations, such as geographical boundaries, that are more prevalent among large organizations, as well as through selection of technologies that are more likely to benefit organizations of this size.

Another purpose of this study is to validate the ability of the situated learning theory as an effective primary learning theory behind the proposed KMS. Although the literature review has demonstrated strong relationships between this theory and OL, technology adoption, and KM, there was a need to see how it can manifest itself in a system design and how well will these elements be received by practitioners of the PPM community.

Finally, this study aims to not only demonstrate the value of the KMS for PPM concept and design it, but also provide an idea of the *magnitude* of a working KMS developed based on the foundations described within. An understanding of the magnitude is important for researchers and practitioners wishing to further develop the concept as it may influence their research strategy and resource allocation.

In order to meet these purposes, this study answers the following two primary research questions:

- Which technical capabilities can facilitate knowledge management and organizational learning in IT Project Portfolio Management environments?
- What should be the design considerations and core technological tools associated with implementation of these technical capabilities?

II--REVIEW OF LITERATURE

Overview

There are four primary knowledge domains involved in this study, each serving a different primary role in the solution framework. Consistent with this view, this literature review consists of four sections representing the four domains. The list below describes the role that each of knowledge domain serves, and the objectives of reviewing its literature in this chapter of the study. While some of these objectives repeat themselves across different sections, they are addressed from different angles with the aim of providing a sound foundation for the remainder of this study.

1. IT Project Portfolio Management - primarily viewed as the *domain* or *learning topic* of this study. This section aims to address the following objectives:
 - a. Convey the general importance of PPM by reviewing its strong theoretical roots, the benefits associated with its adoption, problems caused by the lack of it, and recognition of its value by industry experts.
 - b. Stimulate thoughts about the design of the PPM KMS framework through a literature review of different PPM implementation sub-topics, including typical organizational participants in PPM processes who are expected to be the primary *learners* of the KMS for PPM.
 - c. Validate the existence of the gap that the present study purports to address and characterize it through a literature review of different aspects of the relationship between the PPM and organizational knowledge.
 - d. Confirm the importance of addressing the identified gap by aligning the gap with specific problems caused by it.
2. Knowledge Management and Knowledge Management Systems - primarily viewed as the *instrument* of this study. This section aims to address the following objectives:

- a. Assess the ability of the chosen instrument to address the identified gap by reviewing its robust theoretical foundations and potential organizational benefits gained by it.
 - b. Characterize the identified gap and confirm the importance of addressing it through review of knowledge processes in PM, a field that strongly overlaps with PPM.
 - c. Stimulate thoughts about the design of the PPM KMS framework as well as the methodology that can be employed to develop it based on the following:
 - i. Review of system design theories for KM applications.
 - ii. Review of a sample KM framework for Research and Development (R&D), an area that is highly related to PPM, as well as two KM frameworks for PM.
 - iii. Review of studies about primary knowledge challenges in organizations, such as geographical barriers.
 - iv. Review of knowledge processes in the field of PM.
 - v. Review of key concerns associated with KM implementations.
3. Organizational Learning - primarily viewed as the *objective* of this study. This section aims to address the following objectives:
- a. Stimulate thoughts about the design of the KMS framework based on review of fundamental OL questions such as the relationship between individual and OL, factors influencing OL, and its measurement approaches.
 - b. Confirm the importance of addressing the identified gap based on a review of studies suggesting a positive relationship between OL and organizational performance.
4. Situated Learning theory - viewed as the primary *learning theory* supporting this study. This section aims to address the following objectives:
- a. Assess the suitability and enhance the understanding of the theoretical foundations behind the proposed framework by reviewing the following groups of studies:

- i. The theory's relevance to the chosen instrument (KM).
 - ii. The theory's relationship and applicability to the study's objective (OL).
- b. Stimulate thoughts about the design of the KMS based on a review of the theory's elements and how they can manifest themselves in the proposed design.

IT Project Portfolio Management

Definition, Theoretical Foundations, Importance

Harry Markowitz (1952) proposed the Modern Portfolio Theory (MPT) as an investment theory representing the mathematical concept of diversification, work for which he has been awarded the Noble price in economics. Specifically, MPT is focused on methods for determining the specific mix of investments generating the highest expected return for a given level of risk, or minimizing the risk for a given expected return. Although MPT was initially developed by Markowitz specifically for financial investments and despite theoretical and practical criticisms that have been leveled against it, its concepts found their way to other areas throughout the years.

One of these areas is IT PPM, a discipline which has been established when Warren McFarlan (1981) demonstrated how some of the MPT concepts could be applied to IT projects. McFarlan suggested that the general poor performance of Information Systems (IS) projects is associated with three main deficiencies in management practices: failure to properly assess the risk of individual projects or the aggregate risk of project portfolios, and failure to apply adjusted managerial approaches to different projects based on their natures.

Key project risks include an inability to obtain the anticipated project benefits, cost overrun, and failure to deliver the project result on time; these factors are strongly affected by further dimensions such as project size, prior experience of the organization with the technology, and the structure of the project.

McFarlan therefore suggested that management should employ a consistent and well thought out risk-based approach to the selection and management of IT projects, as well as calculating and controlling the aggregate risk profile for the IS portfolio as a whole. The third IS deficiency, failure to apply different managerial approaches to differing projects, should be addressed through the selection of appropriate PM methods based on the degree of project structure and the company-relative technology. These methods fall into the following four types: *internal integration methods*, aimed at ensuring that the project team operates integrally; *external integration tools* link the project team's work to the "external world."; *formal planning tools* help structure the tasks and estimate project schedule, scope, cost, and resources; *formal control mechanisms* allow managers to track project progress and identify potential risks.

Since the concept of PPM was first suggested by McFarlan, it has become a fairly popular research topic in the field of Information Systems. Kumar & Ajjan & Niu (2007) proposed an elegant definition of the term, which covers its key objectives: "Continuous process to manage IT project, application and infrastructure assets and their interdependencies, in order to maximize portfolio benefits, minimize risk and cost, and ensure alignment with organizational strategy over the long run" (p. 2). While PPM definitions may vary, there seems to be a consensus in the literature concerning the underlying belief of PPM that IT assets such as hardware or software should not be perceived as costs or expenses but rather as investments capable of yielding measurable returns over time (Broadbent & Weill, 1997).

PPM awareness has also strongly permeated organizations in recent years. For example, in a publication by Jeffery and Leliveld (2004), 130 Chief Information Officers of Fortune 1000 companies were interviewed about their organizations' adoption of PPM; the results showed that 89% of the CIO's were very aware of it and 65% believed that the approach yields significant business value. Nonetheless, the Management Information Systems (MIS) literature also recognizes that quantifying the benefits of an IT project portfolio can be difficult, primarily for infrastructure projects or projects that are influenced by complementary investments in training and business processes (Weill & Aral, 2006). It is therefore also difficult to quantify the benefits of PPM

implementations, and 82% of the Jeffrey's and Leliveld's survey respondents (2004) identified the ability to estimate IT benefits as a major challenge.

Nevertheless, Jeffrey's and Leliveld's article suggested a statistical link between mature PPM processes and return on assets (ROA), and outlined ten benefits mentioned by IT executives as positive outcomes of PPM adoption: 1) Improved business strategy alignment 2) Centralized control over IT investments 3) Cost reduction 4) Communication with business executives 5) Improved return on investment 6) Improved customer service 7) Professional respect 8) Competitive advantage 9) Simplified IT integration during mergers and acquisitions 10) Improved decision-making. Finally, one strong logical explanation for why PPM is important is because most organizations have more project ideas than they have resources to carry out (Archer & Ghasemzadeh, 1999).

An alternate way of demonstrating the importance of PPM is through a review of studies that have reported on organizational problems caused by *lack* of PPM approaches. For example, Weill and Aral (2006) reported that such organizations are likely to invest in projects that do not add value or add value that is misaligned with the organizational strategy. A second study reported on a tendency of projects' failure because of an inability to assess individual project risk or aggregate risk of the entire portfolio (McFarlan, 1981). A third study described a state of intra-institutional competition among projects for resources and existence of project overlaps (Thorp, 1999). Finally, Jeffery and Leliveld (2004) described cross-functional communication and lack of organizational agility for major changes as additional symptoms of organizations that are lacking PPM approaches.

PPM Implementations, Pre-conditions, Patterns, and Participants

Since an organizational adoption of PPM approaches is considered to be a major undertaking, several papers discuss pre-conditions for PPM implementations. Rosser and Potter (2001), for example, described a certain role and perception of IT in the organizations as an important pre-condition. They suggested that prior to the implementation, organizations should strive to transform the IT organization into a

"business within a business", that is a source of growth and innovation so that its people can provide options for moving the organization forward.

A second pre-condition for PPM implementations suggested by Santhanam and Kuparisis (1995) is related to organizational strategy and includes adoption of strategic planning practices that identify and exploit strengths while fostering greater alignment with the organizational objectives. In such an environment, all the stakeholder groups must jointly develop strategic plans based on a common understanding of the organizational strengths.

Finally, a number of studies described PPM implementation pre-conditions that are more directly related to the actual implementation: Cameron (2006) stressed the importance of developing portfolio objectives, measurable expectations and risk and rewards boundaries; Weill and Broadbent (1998) suggested that as a pre-condition for an effective identification, evaluation and integration of new technologies, the organization must first decide how much to invest in Research and Development; Jeffery and Leliveld (2004) stressed the importance of executive commitment, similar to any other major organizational undertaking, as well as involvement of the business side of the organization in the initiative, as a key to bridging the desired business-IT gap; Grushka-Cockayne et al. (2005) suggested that the organization must ensure the project team has the relevant finance, strategy, PM and technical skills, if the PPM implementation is enabled through a software tool

Participant or stakeholder analysis is an important step of PPM implementations designed to identify key players who have a stake in PPM and their attributes so they can be properly addressed. Maizlish & Handler (2005) suggested a structured process for PPM stakeholder analysis, comprised of four steps; the first step includes distinguishing between stakeholders with formal or informal power where formal power can often be associated with funding ability and informal power relates to the ability to influence others; second step includes identification of stakeholder groups, such as project managers; third step includes collection attributes of key stakeholders such as perceived level of PPM support, power level, learning/communication style, perceived risks with PPM, and primary business concerns; last step includes addressing stakeholders based on their attributes.

Maizlish and Handler (2005) identified the following groups as the most common stakeholder groups in PPM implementations: senior management, line of business management, IT management (e.g. IT strategy executives, IT portfolio analysts), IT staff (e.g. Project Managers, Program Manager), and business partners.

PPM Implementation Challenges and Relationship to Organizational Knowledge

As mentioned earlier, Jeffery and Leliveld (2004) reported that most CIO's are very aware of PPM and its business value. However, only a few organizations (17%) appeared to be realizing PPM's full value based on their lack of adoption of key PPM elements such as central oversight over the IT budget, proper documentation of IT assets, central project tracking or project tracking benefits. Several implementation challenges dominate the literature, all of which have a strong relationship to organizational knowledge, hence the relationship to the present study.

The first challenge is related to the fundamental management concept of IT and business alignment, according to which projects undertaken by the organization should be a reflection of the organizational strategy and directly linked to components of the strategy they support (Cooper & Edgett & Kleinschmidt, 1997). However, the expected correlation between strategy and the project portfolio aimed to ensure that projects with the biggest desired strategic impact are undertaken remains an inexact science in organizations today (Archer & Ghasemzadeh, 2000; Dietrich, Poskela, & Artto, 2003). Chan and Reich (2007) suggested that the IT and business alignment problem is primarily related to knowledge: often, IT executives do not possess sufficient knowledge of the organizational strategy and business executives are not always knowledgeable enough about IT.

The second challenge is related to skills and resources: 46% of the respondents in Jeffery's and Leliveld's study reported that their IT staff lacked basic working knowledge of financial concepts, making it hard to adopt a process that has strong roots in finance. Since such knowledge does exist in modern firms, effective KM processes could have helped in mitigating the problem.

The third challenge is related to metrics and measurement process: 82% percent of the survey respondents in Jeffery's and Leliveld's (2004) study identified the ability to estimate IT benefits as a major challenge. The respondents indicated that the challenge is related to three problems: a third of the respondents never established baselines to compare project benefits against, 30% reported that project scope changed too often, and 13% indicated that IT investments lacked known objectives to base the evaluation against.

Knowledge Management

Background and Historical Overview

The definition of the term *knowledge* is a question that occupied philosophers since the Greek era and has been defined in numerous ways throughout the years. Several definitions of the term that are relevant to the field of KM include: "knowledge is the whole set of insights, experiences and procedures that are considered correct and true and that therefore guide the thoughts, behaviors, and communications of people" (Van Der Spek & Spijkervet, 1997, p.1-3) "knowledge is reasoning about information and data to actively enable performance, problem solving, decision-making, learning, and teaching" (Beckman, 1997).

The term knowledge also has many different dimensions, most of which are relevant to the field of KM. The first dimension, knowledge accessibility, was suggested as part a leading framework proposed by Nonaka and Takeuchi (1995) that classified knowledge accessibility into two categories: *tacit knowledge*, defined as knowledge that people possess but may not be aware of it or realize how it can be valuable to others; and *explicit knowledge*, knowledge the individual holds in mental focus, and can be easily communicated to other individuals.

The second knowledge dimension relevant to KM is knowledge storage media: the media in which knowledge can reside such as paper document, computer or the

human mind. The third dimension, knowledge hierarchy, represents a premise that knowledge be organized into a hierarchy. Several researchers proposed knowledge hierarchy models, such as Beckman (1997), who defined a five level knowledge hierarchy: data → information → knowledge → expertise → capability. 4) Knowledge creation (e.g. innovation) vs. the transfer of “established knowledge” within a group (Bray, 2005)

Peter Drucker, one of the leading theorists of modern organizations, offered in his book "Post-Capitalist Society" (1993) a number of key insights into the role of knowledge in a variety of historical settings and viewed knowledge as a defining characteristic of the new "era". He wrote: "The function of organizations is to make knowledges productive... Knowledges by themselves are sterile. They become productive only if welded together into a single, unified knowledge. To make this possible is the task of the organization, the reason for its existence, its function" (p. 117).

The interest in KM, which has seen a surge in the late 1990s, is understood as a response to the growing importance of knowledge described by Drucker on one hand and the distributed nature of organizations that is stretched across space and time on the other hand. It builds upon and extends the resource-based theory of the firm initially promoted by Penrose (1959) and is contributed by different fields such as business administration, information systems, computer science, public health, and public policy. One of the most popular definitions of the term, which broadly scopes it out is as any process or practice of creating, acquiring, capturing, sharing and using knowledge, wherever it resides, to enhance learning and performance in organizations (Quintas et al., 1997; Prusak, 1997).

A review of the organizational KM literature shows that the literature deals with the practice from four primary perspectives: 1) Organizational Learning 2) Information Systems 3) Strategy 4) Management. In the context of this literature review, the focus will be on the first two.

Organizational Knowledge Management from an Organizational Learning Perspective

Prior to the coinage of the term “Knowledge Management”, March (1991) presented an OL model which attempted to maintain an appropriate balance between *exploration* (e.g. discovery, innovation) and *exploitation* (e.g. execution, implementation) as a primary factor in system survival and prosperity. He suggested that a “mutual learning” process occurs in organizations, as organizational knowledge is diffused to individuals through various forms of instruction while, at the same time, the organizational code is adapting to individual beliefs. March’s model defined an individual knowledge level as the proportion of external reality accurately represented by an individual knowledge vector. Similarly, the organizational knowledge level is defined as the proportion of reality correctly represented by the organizational code.

Nonaka (1994) published the seminal article about KM from an OL perspective. The central theme of the paradigm for managing the dynamic aspects of organizational knowledge proposed in his paper was that organizational knowledge is created through a continuous dialogue between tacit and explicit knowledge. He argued that while new knowledge is developed by individuals, organizations play a critical role in articulating and amplifying that knowledge by providing the forum for a "spiral of knowledge" creation. This knowledge spiral consists of four stages: *socialization*, creation of tacit knowledge through shared experience; *combination*, creation of explicit knowledge from explicit knowledge; *externalization*, conversion of tacit knowledge into explicit knowledge; and *internalization*, conversion of explicit knowledge to tacit knowledge. Nonaka’s paper was the first to argue that OL goes beyond “internalization” which is only one of the four modes of conversion required for creation of new organizational knowledge.

Organizational Knowledge Management from an Information Systems Perspective

Schultze and Leidner (2002) analyzed the IS literature on KM using a framework developed by Deetz (1996) with the objective of identifying the possible theoretical perspectives of KM and assessing the extent to which these diverse perspectives are

represented in the KM literature. They classified the KM/IS literature into four scientific discourses.

The *normative* discourse represents research with the goal of establishing law-like relations among objects. It primarily focuses on the discovery of technology solutions to knowledge problems such as discovery in databases, development of organizational information systems, and monitoring of email usage. The *interpretive* discourse represents research with the goal of displaying a unified culture. Unlike the normative discourse that treats knowledge as an independent variable, the interpretive discourse does not study knowledge directly but instead focuses on the role of technology in supporting knowledge work. The *critical* discourse represents critical research with the hope of a social order. Finally, the *dialogic* discourse represents research with the goal of reclaiming a conflict surrounding the contradictory nature of managing knowledge.

Their study's results showed that KM/IS research is biased toward the consensus discourses in general and the normative discourse in particular, meaning that the negative implications of knowledge are largely unexamined. Although some of the articles under the interpretive discourse emphasize the negative consequences of IS on OL, they do not question the value of knowledge itself, which is something that Schulze and Leidner warn against.

Alavi and Leidner (2001) framed the role of IS in KM in an influential study. While knowledge, according to their definition, represents information possessed in the minds of individuals, they suggested alternative representations of knowledge for different data items, with IS serving an important role in the management of the knowledge in each case. They determined that "Advanced information technologies can be used to systematize, enhance, and expedite large-scale intra- and inter-firm knowledge management" (p. 108).

The supporting role of IS in KM, as suggested by Alavi and Leidner, can be divided into four processes: 1) Knowledge creation. 2) Knowledge sharing. 3) Knowledge transfer 4) Knowledge application. While from an IS view the distinction between data, information, and knowledge is highly debatable, Alavi and Leidner

suggested that KM systems, unlike other forms of IS, are geared towards capturing the users' knowledge and enable them to assign meaning to information. Practically speaking, Alavi's and Leidner's study identified three primary application of IS for KM: 1) Creation and sharing of best practices 2) Creation of corporate knowledge directories 3) Creation of knowledge networks.

Alavi and Leidner (1999) analyzed the expectations, benefits, and challenges associated with KM system implementations, based on a questionnaire given to 109 participants from 12 different countries, ranging from CIO's to IS managers and functional area executives. As expected, these practitioners did not value KM for the sake of knowledge as an end in itself, but only when it was perceived to be capable of bringing desirable organizational benefits. The expected benefits were broken down into *process outcomes* such as enhanced communication and greater overall efficiency and *organizational outcomes* such as improved service and financial results.

The respondents of the study were also asked about their key concerns in relation to KM systems. The managers expressed concerns over cultural, managerial and informational issues. The *information concerns* specified by the participants included: building vast amounts of data into usable form, avoiding overloading users with unnecessary data, eliminating wrong/old data, ensuring customer confidentiality, keeping the information current. The *management concerns* specified by the participants included: change management implications, getting individuals to volunteer knowledge, getting business units to share knowledge, demonstrating business value, bringing together the many people from various units, determining responsibility for managing the knowledge. The *Technology concerns* specified by the participants included: determining infrastructure requirements, keeping up with new technologies, and security of data on Internet.

While the expected outcomes and most of the concerns related to KM initiatives mentioned by the respondents are highly applicable to KMS for PPM, it is important to denote that since the study focused on KM in general, it might have missed certain important findings that are more specific to the present study.

Another limitation of this research is related to the fact that it was conducted at a time when KM systems were just beginning to appear in organizations (10 years ago). Related to that, some of the participants did not even implement KM at the time their responses were elicited and expressed a need to better understand the concept and be convinced that KM "works" and is more than just another "fad". Another evidence of this limitation is apparent from the list of technological concerns raised by the participants, which included items such as bandwidth, and a consistent suite of email products, both of which tend to be less of a concern in large corporations these days.

Knowledge Management Framework for R&D – Sample Framework.

Ross et al. (2001) have studied KM processes in R&D organizations, including PPM, and proposed KM recommendations for R&D managers by following a structured process comprised of 4 steps.

In the first step, they identified a model for knowledge flow in R&D processes that could be used as a visual point of contact for discussions around the key issues R&D managers face and the ways of managing knowledge flow. The knowledge flow included highlight of KM aspects that are unique or especially important to R&D processes and followed these guidelines: 1) It was driven by overall organizational strategies and goals that cascade down to the R&D organization. 2) Knowledge sources were identified and represented as a continuum from tacit to explicit knowledge. 3) The "expanding element" occurring when individuals and teams discuss the information they obtained and create new knowledge during such discussions was taken into account. 4) The decision-making progress in which ideas are prioritized and certain programs are initiated was taken into account as well because of its power to generate new knowledge during and after implementation of these programs.

In the second step, they conducted interviews and distributed of surveys to R&D managers of 19 participating organizations, asking them to identify their highest priority KM issues, based on the knowledge flows. The list of highest priority issues, which are

also applicable to other knowledge domains, included: A) what kind of culture facilitates knowledge flow and how can it best be designed, incorporated and managed? B) How can the knowledge of experts and people leaving the organization be captured? C) What can be done to accelerate the R&D process? D) How can the creativity envelope within the R&D organization be expanded?

In the third step, they have highlighted a list of KM imperatives, based on the knowledge flow developed in first step, list of known KM enablers, and the issues reported by the R&D managers: A) Broadly instill the goals and strategies of the organization. B) Enhance access to the tacit knowledge of the organization. C) Provide easy "search and retrieval" tools for internal and external information. D) Promote creativity. E) Capture new learning for reuse. F) Provide a supportive culture.

In the fourth step, they proposed a list of "better practices" that R&D managers can use to facilitate knowledge flow and the knowledge creation processes based on the list of KM imperatives developed in the third step. The list of "better practices" was developed based on their A) Visibility and clear ability to drive value. B) Focus on the need/process rather than the tool. C) Ability to constructively change the way people access and share knowledge D) Finish with a self-consistent set. The following is the list of the identified "Better Practices" in an abbreviated form: A) "Balanced Scorecard" based upon appropriate weights and metrics to a slate of key process initiatives. B) Expertise/Skills database as a means of understanding the breadth and depth of knowledge within organization and making it easier for individuals and teams to find other individuals with sought after skills. C) Portals that provide broad access to many knowledge bases. D) Intellectual Property Analysis as a means of opportunity identification. E) Team learning through project execution. F) Elimination of organization silos known to be knowledge barriers.

Both the methodology employed in Ross's study and some its outcome "better practices" are believed to be relevant and useful for the present study, yet contains several known limitations. On one hand, the number and identity of the participating companies in this study, coupled with the direct feedback on the list of "better practices" add to its

validity as an important source. On the other hand, several factors limit the significance of this study, both in absolute terms and in relation to the present study.

First, it is known that although R&D processes and PPM processes have some common characteristics, such as the selection process of new initiatives or the interaction with new technologies, they also differ in a number of ways. For example, research activities, compared to project management, tend to be less structured and predictable in nature. Second, the knowledge processes which were used as basis for the recommendations were admittedly oversimplified by the authors. For example, these processes suggest a once-through linear operation, which is highly inaccurate. In reality, in each step of the process, such as idea creation or decision-making, new knowledge can be created, captured, accessed, and utilized. Third, the research results had not been externally benchmarked against alternatives. Also, as reported by the authors, surveyed companies refused to share some of their practices which they deemed as proprietary, which could potentially be highly valuable for KM.

Knowledge Processes in Project Management

A project is defined by the Project Management Institute (PMI) as "A temporary endeavor undertaken to create a unique product, service or result" (p. 17) and the field of PM, developed from different fields of application including construction, engineering and defense, is defined by PMI as "The application of knowledge, skills, tools, and techniques to project activities to meet the project requirements" (p. 20).

Projects always produce new knowledge, including technical, procedural and organizational knowledge (Kasvi, Vartiainen & Hailikari, 2003). An important conceptual difference emerging from the cross-project learning literature is the difference between *process* and *product knowledge*. Process knowledge was found to be more valuable for cross-project learning due to its generic nature, despite the fact that it tends to be tacit and context-sensitive, making it hard to transfer. On the other hand, product knowledge, due to its project specific nature, tends to be less valuable for cross-project

learning (Bresnen et al, 2005; Newell et al, 2006). Thus the challenge of KM in project environments is the creation, administration, dissemination and utilization of newly generated knowledge (Kasvi, Vartiainen & Hailikari, 2003) and exploitation of the knowledge gained in historical projects has the potential to improve the key dimensions of projects - quality, cost and schedule (Durbin & Wheeler, 2002; Owen, Burstein, & Mitchell, 2004; Fernie, Green, Weller & Newcombe, 2003).

However, organizations usually risk losing the valuable knowledge created during the project due to a number of common attributes of project environments: project teams typically disassemble at the end of a project, people often change during the project, project team members are often geographically dispersed and have different backgrounds (Kasvi, Vartiainen & Hailikari, 2003). This, in turn, leads to risks such as repeating mistakes, resource wastage and others.

For this reason and others, both academic studies and professional project management organizations recommend capturing the valuable project knowledge and helping the organization acquire it, in one form or another. For example, the PMI recommends on officially capturing "lessons learned" of projects "so that they become part of the historical database for both the project and the other projects of the performing organization" (p. 167) and the literature confirms that it is by far the most common learning oriented activity in project environments (Disterer, 2002). Lessons learned are typically gathered as part of a project "post mortem" review and different scholars have proposed defined processes for optimizations of post mortem sessions (Birk et al, 2002; Collier et al, 1996).

While projects' lessons learned are typically stored in an electronic format and placed in a shared location, there is no evidence in the literature of a successful utilization of this knowledge in future projects. Julian (2008) identified four barriers for an effective use of lessons learned practices: 1) Team members' belief that their project is too unique to have its lessons learned applied to other projects. 2) Time pressures that reduce or eliminate formal time for learning and reflection. 3) "Political" fears related to the need to "point fingers" at other team members as part of the lessons learned capture. 4) Tendency to defer learning and reflection activities until the close of the project.

Alternatively, joint work among communities of practice has proven to be more effective than technological approaches (Newell 2004, Prencipe & Tell, 2001), which can take the form of debates, brainstorming session, mentoring etc (Liebowitz & Megbolugbe, 2003). However, often the limited time span of the project does not allow for creation of a sufficient level of trust among the project team, that is necessary for transfer of tacit knowledge (Nicholas, 2001). In addition, the literature also reports on the important role that senior managers play in cross-project facilitation through creation of connections between project teams (Cleland,1988; Brensen et al., 2003; Newell et al., 2006).

While studies on KM for PM are still sparse, a number of researchers proposed frameworks or guidelines for KM in project environments and two of them will be briefly described.

Ayas (1996) proposed a structural approach to PM learning based on the Organizational Learning Theory and the social nature of situated, tacit knowledge. She proposed a project network structure model utilizing social networks as a means of converting tacit knowledge to explicit knowledge among team members. She claimed that "The project network structure enables effective learning with project management because it enhances knowledge creation and improves the quality of information transfer within and between projects" (p. 1) . In subsequent research, Ayas claimed that her model was proven successful in reducing the cost and schedule of product development projects (Ayas & Zeniuk, 2001).

Kasvi, Vartiainen, and Hailikari (2003) examined program and project KM frameworks utilized by the Finnish government and concluded that the observed KM practices were weak and unsystematic. Based on a series of interviews and questionnaires they proposed the following high level guidelines for KM in project environments: 1) Identify KM as a critical project competence. 2) Ensure that the projects themselves are systematically managed as a pre-requisite for an effective KM. 3) Ensure that team members feel that they gain personal benefit from experience documentation and perceive its utility (Landes & Schneider & Houdek; 1999). 4) Manage both substance and context knowledge throughout the whole project process.

Organizational Learning

Overview and Definition

OL is a field within organizational theory that studies the way organizations learn and adapt. OL has both a lengthy history and a broad range of academic disciplines studying it, each from a different perspective and using different terms and definitions. Crossan and her colleagues (1999) concurred that “different researchers have applied the concept of organizational learning, or at least the terminology, to different domains” (p. 522). Hence, there is no uniform understanding of organizational learning and there may never be one shared widely.

For example, while economists tend to focus their OL research on the outcomes of the learning, such as new product development or improved productivity, organizational theorists and psychologists tend to examine the processes of learning at an organizational level. This variance appears to be along three key dimensions: 1) Cognition and behavior – the relationship between knowledge, comprehension, action and learning. 2) The unit of analysis - learning at an individual level, team, organizational or inter-organizational levels. 3) Correlation between OL and organizational performance.

Despite the variance among the different disciplines, there seems to be a general consensus in the literature around two key assumptions: first assumption is that OL has positive consequences despite the fact that the outcomes of learning may be negative; second assumption is that learning occurs throughout all the organizational activities, whether formal or informal, at different speeds and levels. Hence, organizations should encourage and coordinate the variety of different interactions.

While the different perspectives of OL define it differently, some of the highly cited definitions of the field include Huber’s (1991) “change in the range of an organization's potential behaviors, which may or may not contribute to enhanced

effectiveness” (p. 89); and Fiol’s and Lyles’s (1985) "The study of organizational learning considers organizations to be cognitive entities, capable of observing their own actions, experimenting to discover the effects of alternative actions, and modifying their actions to improve performance”.

“*Learning Organizations*”, a key term in the field of OL, are organizations that have in place mechanisms and processes to enhance and optimize OL (David, 1993) and can be characterized, according to this definition, as organizations that: 1) Adapt to their external environment. 2) Continually enhance their capability to change/adapt. 3) Develop collective as well as individual learning. 4) Use the results of learning to achieve better results.

How do Organizations learn and what Influences Organizational Learning?

Naturally, one of key questions examined in the field of OL is how organizations learn and different scholars have proposed models for facilitation of OL. Some of the key models shall now be described.

Argyris and Schon proposed the first model for OL facilitation in 1978. Similar to approaches to individual learning, they distinguished between single-loop and double-loop learning. Single-group learning is the process according to which the learning units (individuals, groups or organizations) change their actions based on the differences between expected and actual outcomes. Double-group learning, on the other hand, is the process according to which the learning units challenge the assumptions, rules, and values that led to the actions in the first place and change them.

Argyris and Schon further suggested that organizations need to learn how to carry out single and double-loop learning, which they called *deutero-learning*: “When an organization engages in deutero-learning its members learn about previous contexts for learning. They reflect on and inquire into previous episodes of organizational learning, or failure to learn. They discover what they did that facilitated or inhibited learning, they invent new strategies for learning, they produce these strategies, and they evaluate and generalize what they have produced” (1978, p. 3-4).

A number of studies (e.g. Bierley & Chakrabarti, 1996; Dodgson, 1993) suggested that OL can occur in two ways: either from the organization's own experience through trial and error or from the experience of other organizations, referred to as vicarious learning, congenital learning, or grafting (Huber, 1991). Empirical studies that examined the phenomenon of experiential learning and its outcomes found that while organizations do learn from their cumulative experiences, other organizational factors such as systems and procedures better explain the phenomenon of OL (e.g. Grewal et al., 2001; Soreneson & Stuart, 2000; Darr et al., 1995; Pisano et al., 2001). Other studies that examined the second way of learning, from other organizations, primarily focused on characterizing different scenarios of such learning but did not delineate the conditions under which the organization establishes a link to another organization for the purposes of learning (e.g. Baum & Ingram, 1998; Ingram & Baum, 1997)

March and Olsen (1975) attempted to establish an association between individual and OL. They suggested that the following cycle repeats over and over in organizations: Individual beliefs → Individual actions → organizational action → Response from the environment which may influence individual beliefs. During this cycle, the learning process occurs when the individual beliefs improve.

The empirical OL research found that various organizational factors influence OL, which can be classified into two categories: internal and external. Studies examining the internal factors have found that these factors include the organizational culture, organizational strategy and structure (Carroll, 1998; Bierly & Chakrabarti, 1996; Attewell, 1992). Studies examining the external factors have found that these factors include the organization's position in the industry, its access to resources and nature of the competitive dynamics in the industry impact an organization's learning (Barnett & Hansen, 1996; DeCarolis & Deeds, 1999; Gulati, 1999).

The Learning Subject or who or what is doing the Learning?

On one hand, some researchers argued that learning can only occur at an individual level, that organizations themselves do not learn (Dodgson, 1993) and that the main actor in OL is always the individual (Argyris, 1996; Senge, 1990). Some researchers have even cautioned against materializing the organization (Simon, 1991).

On the other hand, other researchers argued that organizations learn at social levels (March, 1991; Dunphy, Turner and Crawford, 1997) and that OL is more than just the sum of the learning of its members. Organizations can establish learning systems that influence active and future members through such means as policies, norms and values (Fiol and Lyles, 1985). Regardless of the stance taken by each side, it is clear that capturing individual learning is the first step to making the knowledge useful for the organization.

In what way does Organizational Learning differ from Individual Learning?

This question is strongly related to the previous question --- assuming that organizations can learn, in what way is this learning different than individual learning? Although this question is one of the most debated questions in the field of OL, studies attempting to answer it largely relied on individual learning theories developed by cognitive psychologists (Holman, Pavlica and Thorpe, 1997).

For example, one popular approach is to try and apply what is known about the learning of individuals to organizations, examine the suitability of these concepts to organizations, and realize what types of knowledge can only be learned by individuals and vice versa (cf. Cohen and Sproull, 1996). However, some studies argued that the two learning processes have not been methodically and empirically compared and that it has simply been assumed that a somewhat analogous process exists in both of them (Lähteenmäki & Toivonen & Mattia, 2001).

How to Measure Organizational Learning?

There are two main methods for OL measurement, positivist and interpretive, that mirror the distinction between cognitive and constructivist theories of OL. On one hand, a large number of researchers argued for qualitative studies through such means as interviews and are interested in phenomena such as "communities of practice" (Lave & Wenger, 1991). On the other hand, others argued for the need to develop more accurate, valid and reliable methods, such as surveys, for measurement of learning across organizations (Gallagher and Fellenz, 1999), which perceive the organization as the primary unit of analysis.

These two methods were applied to two different approaches to the measurement of OL: The first approach, *outcome measures*, focuses on measuring the outcomes of organizational actions, attempts to infer learning from changes in outcomes over time and derives a learning curve based on that inference. For example, Epple, Argote and Devadas (1991) studied the transfer of learning outcomes between shifts in a manufacturing factory. Learning was inferred based on changes in production rates, and deductions were made about the relative effectiveness of learning from experience versus acquired knowledge.

Unlike the outcome measures approach that does not observe the learning process directly, the *process measures* approach attempts to perform a direct examination of the learning process. Crossan et al. (1999) proposed a theoretical framework describing four OL activities that may guide measurement of the OL processes: *intuiting*, the preconscious recognition of the opportunities inherent in a personal experience; *interpreting*, the explanation of an idea to oneself and to others; *integrating*, development of a shared understanding and coordinated actions among a group of individuals; and *institutionalizing*, the process of ensuring that actions are made routine.

Organizational Learning and Project Portfolio Management Capabilities.

Killen, Hunt and Kleinschmidt (2008), in a unique study, have investigated the development of PPM capabilities in six successful organizations across diverse

industries, with the purpose of understanding the contribution of OL investments to organizational capabilities such as PPM.

Their research findings showed that OL processes promote the continual development of PPM capabilities to keep them aligned with a changing environment. Specifically, PPM capabilities have shown to co-evolve through a combination of tacit experience accumulation, explicit knowledge articulation and explicit knowledge codification learning mechanisms. In particular, they suggested that effective PPM capability will require "particularly strong investments in enhancing tacit experience accumulation mechanisms and explicit knowledge codification mechanisms during the initial establishment or during periods of radical change to the PPM process" (p. 1).

Although the study focused on new product development projects and not specifically on IT projects, the two domains contains many common attributes and therefore its findings are encouraging in the context of the present study.

The Situated Learning Theory

Overview

The situated learning theory (Lave & Wenger, 1991) has its roots in the pragmatists' notion that knowledge is not an absolute entity, but rather can only be defined in relation to a specific context or situation (Dewey, 1938; James, 1963). It is a general theory of knowledge acquisition that is concerned with how learning happens every day "not an educational form, much less a pedagogical strategy" (Lave & Wenger, 1991, p. 40). This theory is based on the assumption that the learning process is inherently social and argues against views of learning that focus on individual acquisition, internalization and transfer of knowledge.

The first key principle of the theory is that learning is "situated", it takes place in the same context in which it is applied, and is a function of the activity and culture in

which it occurs. This view contrasts most classroom learning activities which tend to expose students to abstract and out-of-context knowledge.

The second key principle is that social interaction is a critical component of learning, in the form of learners' involvement in a "*community of practice*" (COP). COPs are groups of people who engage in a process of collective learning and interact regularly, whether intentionally or incidentally. As part of the shared interest, members engage in joint activities, help each other, and share knowledge.

The three key concepts of the term, in this context are: *knowledge* - the ability to participate in a community of practice, *learning* - becoming a member of a community of practice, *tools* – used to facilitate interaction in a community of practice. The theory shaping this view of social learning was progressively elaborated in later studies by Lave and Wenger and others. For example, Wenger (1998) expanded the concept of COP to further develop a social theory of learning. In this expanded theory, practice is seen as a component of four key dimensions: the source of coherence in a community, a learning process, basis for the social production of meaning, and as the source of boundaries between inter-linked communities.

The situated learning theory has gained much popularity since its inception and has been extensively examined and applied to different areas. Nevertheless, several prominent researchers have criticized it, most notably Anderson, Reder, and Simon (1996). The three have claimed, based on empirical cognitive research, that while cognition is partly context-dependent, as suggested by Lave and Wenger, it is also partly context-independent; that abstract instruction can help as well and that performances benefit from training that is not in a social context.

Situated Learning and Technology Adoption

Algyris and Schon (1996) described a "learning paradox" according to which when organizations take official actions aimed at promoting OL, such as formal training program, they often face resistance that may actually inhibit deeper learning. This

phenomenon has proven to be particularly dominant in adoption of IT as the adopters tend to prefer learning the details of the technology through trusted colleagues, in a way that is situated in nature and consistent with Lave's and Wenger's theory.

Brown (1998) suggested that since the work practices involving the use of technology tend to significantly differ from the way these processes are described in official product manuals situated learning should be regarded as an important, consequential process. COPs may prove to be highly effective in overcoming the learning challenges associated with a new technology and individual learning of the technology takes place in the same context in which it is applied.

In a famous study conducted by Orr (1996), the work of service technicians who specialize in photocopiers was observed through ethnographic methods. He described how the actual techniques employed by the technicians often differ from those described in the official documentation as they rely on the required technical knowledge being a socially distributed resource.

Situated Learning and Organizational Learning

In his book "Communities of Practice: Learning, Meaning, and Identity" (1998), Etienne Wenger suggested that deep OL is best facilitated if the realities of COPs are identified when the change process is designed. "For organizations ... learning is an issue of sustaining the interconnected communities of practice through which an organization knows what it knows and thus becomes effective and valuable as an organization" (p. 8). He therefore suggested that organizations should value the work of community building and ensure that participants of communities have access to the learning resources they need. Wenger suggested the term of "*boundary encounters*" to represent the process of importing practices and perspectives from one community of practices into another, which is key for a deep conceptual change.

Based on the situated learning theory and Orr's empirical investigation described earlier, Brown and Duguid (1991) suggested that the connections between work, OL, and

innovation are apparent in the context of actual communities and actual practices. They claimed that the gap between espoused and actual practices may be too large for non-canonical practices to bridge and in order to foster working, learning, and innovating, an organization must close that gap by: 1) Preconceiving of itself as a community-of-communities 2) Focusing on full-blooded activities themselves rather than on canonical abstractions. 3) Legitimizing and supporting the myriad enacting activities perpetrated by its different members in a nonintrusive way as COPs must be given some liberty to shake themselves free of received wisdom (Nystrom and Starbuck 1984; Hedberg 1981; Schein 1990).

Tyre and Hippel (1991) explored the nature of adaptive learning in organizations by examining the problem-solving process involving the use of new production equipment and concluded that adaptation is a situated process since different organizational settings evoke different assumptions on the part of problem solvers. Hence, they defined learners' context a critical and poorly understood component of adaptive learning processes in organizations.

Situated Learning and Knowledge Management

Situated Learning is the focus of much attention in the KM literature. Several influential KM studies will now be covered, each highlighting a different concept of the situated learning theory in the context of KM.

Wenger suggested the relationship between COPs and KM in his article "knowledge management as a doughnut: Shaping your knowledge strategy through communities of practice" (2004). Wenger began his argument that COPs are the cornerstones of KM by outlining the field's realization of their importance as the social fabric of knowledge. A convincing example of this argument made in the article is that of scientific knowledge, which is really the property of communities that decide what should be regarded as facts and acceptable explanations of these facts or, in his words: "Knowing is not merely an individual experience, but one of exchanging and contributing

to the knowledge of a community. Knowledge from this perspective is what our human communities have accumulated over time to understand the world and act effectively in it" (p. 1).

In the context of KM initiatives, Wenger argued that unless practitioners are involved in the process from an early stage the management of knowledge assets is going to be very limited --- they own the knowledge, understand its effect on performance, how it should be documented etc. Wegner suggested a "doughnut model" for KM initiatives that connects organizational strategy and performance through COPs and contains four main steps: 1) Translate the strategy of the organization into a set of domains. 2) Cultivate the communities according to each domain. 3) Engage practitioners in the development of their practice. 4) Translate the learning inherent in activities into refined practices.

Alavi and Leidner (2001) defined the relationship between context and effective interpretation or application of knowledge as one of the main research questions in the field of KM, though without directly referencing the situated learning theory. They argued that in situations where the context surrounding knowledge creation is not shared, it is questionable whether storing the knowledge without sufficient contextual detail will result in an effective use, which could lead to the knowledge, in essence, being lost (Zack, 1998). A related question outlined by Alavi and Leidner is how much knowledge to code and store. While the more readily available the knowledge is, the more likely its reuse but the risk of knowledge misuse increases, such as in situations when the knowledge is being applied to a different context.

Summary of Literature Review

Since this study is interdisciplinary in nature, the literature review involved a critical assessment of scholarship pertaining to four knowledge domains. In the context of this study, each of these knowledge domains serves a distinct role, while being connected to the other domains in meaningful ways, as initially hypothesized.

The general importance, potential value and interest in PPM – viewed as the learning topic - were demonstrated through several influential studies that either demonstrate these points based on assessment of PPM adoption in organizations, or based on assessment of problems caused by the lack of it (e.g. Jeffery & Leliveld, 2004; Kumar & Ajjan & Niu, 2007). Nevertheless, several studies showed that the actual benefits of PPM adoption tend to be lower than expected (Weill & Aral, 2006; Archer & Ghasemzadeh, 1999). While this gap can be attributed to multiple factors, several studies reviewed in this paper point to individual and organizational knowledge as a primary limiting factor (Chan & Reich, 2007; Jeffery & Leliveld, 2004; Dietrich & Poskela, & Artto, 2003).

The review of PPM literature also provided information that is highly relevant and applicable to the development of the proposed KMS. For example, since individual and OL is the overall objective of the work, a study covering both the typical stakeholders of PPM implementations - the "learners" in the context of the present study - as well as structured approaches for identification of these stakeholders, was reviewed (Maizlish & Handler, 2005). Similarly, the review of PPM implementation pre-conditions, patterns, and typical challenges helped in generating additional ideas related to the proposed KM framework.

While Knowledge problems can be approached in a variety of different ways, KM and KMS - the chosen instruments – appear to have the potential of being an effective tool for addressing the identified gap. The suitability of KM and KMS to the identified knowledge problem was evaluated and demonstrated in three primary ways. First, a review of the theoretical foundations (e.g. Drucker, 1993; March, 1991) and the development of the field have shown that despite its young age, KM has a well-established position in organizations and in the literature (e.g. Nonaka & Takeuchi, 1995; Alavi & Leidner, 2001). Second, a number of studies about KM from an OL perspective showed that KM is more than just a set of practices for knowledge related operations but rather an area that is capable of enhancing OL, the overall objective of the proposed work (e.g. Nonaka, 1994; Cramton, 2001). Third, a review of several successful KMS in areas that are related to PPM provided additional support (e.g. Ross et al., 2001; Ayas, 1996).

In addition to suitability assessment of KM, the review of KM literature also provided additional information related to the identified problem and its proposed solution. The former was accomplished through review of knowledge processes in PM, an area that highly overlaps with PPM. This section demonstrated the importance of managing project knowledge based on review of certain attributes of project environments that make it easy to lose knowledge on one hand while pose major risks associated with knowledge loss on the other hand (e.g. Durbin & Wheeler, 2002; Kasvi & Vartiainen & Hailikari, 2003).

The latter was accomplished through review of techniques and factors that have proven to influence KM in project environments, such as the effect of COPs, and capture of projects' lessons learned (e.g. Disterer, 2002; Newell 2004). Finally, some of the concepts described in a leading IS design theory for KM are expected to be utilized as part of the proposed framework as well (Markus & Majchrzak & Gasser, 2002).

While KM appears to be a suitable instrument, it is no more than a tool for enablement of OL - the overall objective of the present study. Hence, the review of OL literature contributed to the former sections in several ways. First, it stimulated additional thoughts about the design of the KMS through discussion of key OL questions such as the ways in which organizations can learn, assessment methods of OL, the relationship between individual and OL, and the differences between them. Second, the OL literature review also clarified additional factors capable of influencing OL, which have been taken into consideration during the solution design. One example of such factor is learning that occurs from the experience of other organizations (e.g. Bierley & Chakrabarti, 1996; Dodgson, 1993), which could definitely apply to PPM.

The situated learning theory literature review served a dual role of both assessing the proposed approach and influencing it as the same time. For example, the theory's key concepts of contextual learning and COP align with the proposed KMS capabilities and the review of these concepts also helped in further developing ideas related to possible manifestation of these concepts in the outcome framework. This dual role also existed while reviewing the relationships between the theory and three areas: first, several studies describing the relationship between situation learning and technology adoption showed

how applicable the theory is to this area (Algyris & Schon, 1996; Brown, 1998; Orr, 1996); second, several studies demonstrated the strength of the theory's concepts in predicting and facilitating OL (e.g. Brown & Duguid, 1991; Tyre & Hippel, 1991); third, several studies showed how the theory's concepts are in fact some of the cornerstones of KM (Wenger, 2004; Alavi & Leidner, 2001).

III--METHODOLOGY

Overview

The outcome solution design of this study is based on a combination of independent research and input from PPM practitioners. First, an extensive design work was independently performed and only then feedback from external sources was gathered, as basis for validation and refinement of the original design. While gathering feedback from the practitioners, they were asked to comment on the proposed design, and at the same time given stage to express their opinions in an open manner. This approach has not only given the practitioners a starting point without confining them to the original thinking, but also provided a way of conveying the concept of KMS for PPM through description of the proposed capabilities. The three main stages of this overarching methodology shall now be described in greater detail.

First, the research questions were independently answered based on the foundations of the two preliminary studies, additional academic and industry sources, and personal knowledge and experience. As part of this independent work, three core PPM processes have been identified as potential candidates for empowerment by KMS capabilities, four perceived best-fit potential capabilities for each process, and a set of 12 design considerations.

Second, a group of experienced PPM practitioners were asked to comment on the value of incorporating the 12 proposed capabilities into the three processes identified, and outline design consideration associated with implementation of each capability. At the same time, the practitioners were given the opportunity to propose additional capabilities and candidate PPM processes for KMS empowerment.

Third, the original answers to the research questions were refined based on data analysis of the responses. Following the analysis of the participants' responses, an additional literature review was performed with the aim of finding support for the questionnaire's findings that add or contradict the original design. Finally, the original design was refined based on the findings: system capabilities and design considerations were added, existing ones modified, an entity relationship diagram (ERD) of the KMS created, and potential technologies for implementation of these capabilities investigated.

Procedure

A questionnaire was the chosen research method for gathering the necessary input, given the ease of standardizing and analyzing its data, reduced risk of bias compared to methods involving verbal or visual clues, and ability to gather the necessary data relatively quickly. Once a draft questionnaire has been constructed it was pre-tested by a small group of respondents who were asked to comment on its clarity, logical structure, and effectiveness in supporting its intended purpose. The final version of the questionnaire contained the following five sections:

- 1) Mandatory Institutional Review Board participant's rights.
- 2) Three background questions about the respondent's experience in the field.
- 3) Short description of the context of the study, and adopted definition of the term "knowledge", as key to understanding of the proposed capabilities and their differences from traditional PPM capabilities.
- 4) Proposed capabilities section, broken into three sub-sections, one for each of the three PPM processes identified as candidates for empowerment by KMS capabilities. Each sub-section contained the following questions:
 - a. Description of four proposed capabilities, followed by a rating scale of the perceived value of each capability on a scale of 1-5 (1=no value, 5=extremely valuable).
 - b. Open text questions asking respondents to list design considerations associated with the implementation of each capability. These questions were made open text with the aim of adding to the original list of design considerations, and assessing key considerations for the KMS as a whole, without confining the respondents' thinking to the original list. In addition, the free form answers provided means of assessing the face validity of the questionnaire by analyzing the understanding of the proposed capabilities they reflect.

- c. A rating scale question asking respondents to rate the aggregate value of the four capabilities for KM.
- 5) Summary section containing an open text question asking respondents to describe any other valuable KMS capabilities they can think of, whether related to the three chosen PPM processes or any other PPM process.

Once the final version of the questionnaire was ready, members of an online PPM forum, as well as other PPM practitioners were invited to fill it out (N=40). The invitation to fill out the questionnaire stated a minimum of seven years of experience in the field of PPM as a requirement for participation in the study. When in doubt, this requirement has been validated based on different internet resources, and several respondents that did not meet this requirement their responses were taken out of the result set.

Finally, since the questionnaire's questions about design considerations were open text questions it raised the risk of receiving a large number of empty responses, simply out of laziness or time pressure. In order to mitigate this risk, the order of the three processes on the questionnaire was changed twice in the middle of the data collection stages under the assumption that respondents are more likely to answer open text questions at the beginning of the questionnaire.

Data Analysis

Once a set of 40 questionnaires has been gathered, various data analysis operations have been applied to them, at discrete and then aggregate levels. Below is a list of the discrete data analysis operations performed on each question:

Table 1. *Discrete Data Analysis Operations*

Section	Operation	Aim of Analysis
Background	<ul style="list-style-type: none"> Mean and median figures for a question about the number of years of PPM experience. 	<ul style="list-style-type: none"> Assess the suitability level of the respondents to participate in the study, and the overall credibility of

	<ul style="list-style-type: none"> The percentages of respondents holding PPM certifications and PPM publications. 	responses.
Proposed capabilities	<ul style="list-style-type: none"> Mean, median, and standard deviation figures for each of the 12 proposed capabilities' ratings. 	<ul style="list-style-type: none"> Assess the perceived value of each proposed capability. Assess the levels of variations of the perceived values assigned to each proposed capability.
	<ul style="list-style-type: none"> Any design considerations associated with implementation of each capability noted as open text have been standardized and tallied. While a relatively large number of repeating design considerations were given considerable weight in the solution design, no minimum number of repetitions for each design consideration was defined for inclusion in the solution design. 	<ul style="list-style-type: none"> Assess the face validity of the questionnaire by inferring the respondents' understanding of the proposed capabilities through the design consideration which were listed. Identify design considerations outlined prior the questionnaire that may need to be revised. Identify missing design considerations.
Summary	<ul style="list-style-type: none"> KMS capabilities perceived as valuable, whether related to the three chosen PPM processes or any other PPM process have been standardized and tallied 	<ul style="list-style-type: none"> Identify potentially valuable missing capabilities for the three chosen processes. Identify additional PPM processes which may benefit from KMS capabilities.

Table 2. *Aggregate Data Analysis Operations*

Operation	Aim of Analysis
Grand means of mean values assigned to each process's capabilities. Since each process contained the same number of proposed capabilities, calculating the grand means was statistically valid.	<ul style="list-style-type: none"> Assess the overall perceived value of adding proposed KMS capabilities to each process.
Grand means of values assigned to the same capabilities across the three processes.	<ul style="list-style-type: none"> Assess the overall perceived value of each capability across the three processes.
Grand mean of mean values assigned to all capabilities.	<ul style="list-style-type: none"> Assess the overall perceived value of proposed capabilities for proposed processes.
Mean standard deviation across all ratings of all capabilities.	<ul style="list-style-type: none"> Assess the overall variation level of responses.
Mean Pearson correlation coefficient between the mean rating of each process's capabilities and the ratings assigned to the process directly.	<ul style="list-style-type: none"> Assess the internal consistency reliability of the questionnaire.
Top repeating subjects among all the design considerations have been identified and noted.	<ul style="list-style-type: none"> Identify key items that should have a strong influence on the solution design, and future studies.

Limitations of Study

The concept of KMS for PPM is new and broad, and the current study only covered one aspect of it – solution design. KMS implementations entail various other aspects including cultural, organizational, and managerial, none of which have been

thoroughly addressed in this study. Therefore, as solid as the outcome solution design of this study might be, it is important to keep in mind that the path from the outcome of this study to the ultimate objective of this concept – organizational learning – is still long and must thoroughly address the remaining aspects. As one example, many KMS fail to deliver their promised value due to unwillingness of users to share the knowledge they possess (McDermott, 2001), in many cases irrespective of the quality of the KMS's design.

Furthermore, even within the chosen area of focus of this study, solution design, the analysis has intentionally been left at a fairly high level for the reasons mentioned in the purpose of study section. In addition, only design considerations that are specific to KMS have been included, while many other design considerations that are more generic in nature were intentionally not addressed. Therefore, while the outcome of this study may serve as a solid starting point for researchers and practitioners who wish to turn it into a working system, there are lengthy systems analysis, design, development, and testing steps that need to occur first.

For example, system capabilities, at the high-level defined in this study may be viewed by practitioners as highly valuable yet be ultimately implemented in ways that are counter-intuitive and poorly performing to an extent of making them unusable. In other words, not only are the required missing steps lengthy but must also be subject to high quality standards that are necessary in order to produce the desired outcomes.

Another known limitation of this study, similar to most similar studies, is tied to the pace of technological change which sometimes decreases the relevance of studies' outcomes to the field. In order to mitigate this risk, this study strove to minimize references to specific technologies, such as programming languages or operating systems, and instead focused on concepts that are likely to persist even when their implementation tools change. At the same time the possibility of emergence of “disruptive technologies” that would negatively affect the relevance of some of this study's outcomes still exists.

Similarly, the PPM discipline, primarily due its young age compared to other organizational disciplines, tends to be dynamic as well, which introduced yet another risk

for the long term applicability of this study. As a counter-measure against this risk, more weight has been given to foundational PPM concepts – such as selection of the right mix of projects for the organizations or overseeing the active project portfolio – rather than to less central and perhaps temporary trends.

IV--RESULTS

Data Analysis

The questionnaire's results are specified below, in standardized and aggregate forms. The potential capabilities rated by the respondents are presented below in abbreviated forms of the capability descriptions as appeared on the questionnaire:

- “Contextual learning capabilities” - Ability to capture and retrieve relevant knowledge “just in time” (contextual information) during these processes
- “Integration with knowledge repositories” - Integration with internal knowledge repositories such as databases or document repositories (e.g. publish or import relevant knowledge from internal sources).
- “COPs” - Synchronous and asynchronous knowledge exchange with other employees involved in the same processes, including the ability to form groups of domain experts for that purpose.
- “Metrics” - Automated calculation of various metrics which may be used to gain knowledge by people involved in these processes.

Table 3. *Questionnaire Results – Background Questions*

Question	Answer
Years of PPM experience:	8.5 median 9.82 mean
Hold official PPM certification(s)?	24/40 answered “yes” - 60%
Published PPM books/articles/patents?	15/40 answered “yes” - 37.5%

Process A: KM tied to *evaluation, selection, and prioritization* of proposals for projects or programs

Table 4. *Questionnaire Results – Process A*

Proposed Capability	Median	Standardized Design Considerations/Number of Responses

	Mean	
	Std. Deviation	
Contextual Learning Capabilities	4 4.05 0.8	<ul style="list-style-type: none"> • Easy presentable knowledge and easy to access – 10 • Display of knowledge that is truly related to the context is key in order not to overwhelm users – 7
Integration with knowledge repositories	4 3.33 1.27	<ul style="list-style-type: none"> • Ensure document security applies to integrations – 6 • Links to enterprise portal would be very useful – 5 • Mechanisms for management of knowledge quality are key – 3 • Ensure integrations engine is robust and flexible to support integrations with multiple sources – 3 • Put strong emphasis on usability – 6
COPs	3 3.10 0.99	<ul style="list-style-type: none"> • Cannot replace in-person communication - 2 • Integration with existing collaboration tools is key – 9 • Need to keep in mind different teams working in different manners, as a potential challenge – 7
Metrics	3 3.675 1.06	<ul style="list-style-type: none"> • Knowledge quality is key, need to have quality mechanism and processes in places for the metrics to be meaningful – 10 • Standardize metrics at the enterprise level to ensure “apples to apples” comparison - 8 • Should support user-defined metrics – 7

Process B: KM tied to *allocation* of resources for approved projects and programs and *communication* of portfolio decisions and expected outcomes to key stakeholders:

Table 5. *Questionnaire Results – Process B*

Proposed Capability	Median Mean Std. Deviation	Standardized Design Considerations/Number of Responses
Contextual learning capabilities	4 4.03 0.96	<ul style="list-style-type: none"> • Ensuring standardized terminology is key for these capabilities to be effective - 5 • Retrieved knowledge should change as changes to data occur – 1
Integration with knowledge repositories	3 2.88 0.98	<ul style="list-style-type: none"> • Ensure integrations engine is robust and flexible to support integrations with multiple sources – 3 • Put strong emphasis on usability – 7 • Support integration with client tools such as spreadsheets - 1
COPs	4 3.675 0.91	<ul style="list-style-type: none"> • Integration with existing collaboration tools – 8
Metrics	4 3.88 1.19	<ul style="list-style-type: none"> • Knowledge quality is key, need to have quality mechanism and processes in places for the metrics to be meaningful – 10 • Standardize metrics at the enterprise level to ensure “apples to apples” comparison – 6 • Should support user-defined metrics – 6

		<ul style="list-style-type: none"> • Metrics need to account for different project types and other key distinguishing factors - 7
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Process C: KM tied to *periodic performance reviews* of projects and programs. Such performance reviews typically include monitoring of progress against plan, resource utilization, and alignment of active projects and programs with organizational strategy:

Table 6. *Questionnaire Results – Process C*

Proposed Capability	Median Mean Std. Deviation	Standardized Design Considerations/Number of Responses
Contextual learning capabilities	5 4.57 0.83	<ul style="list-style-type: none"> • Ability to publish knowledge should be role based – 4 • Human factor risk – people might feel threatened to capture this knowledge electronically - 1
Integration with knowledge repositories	3 3.15 1.15	<ul style="list-style-type: none"> • Ensure integrations engine is robust and flexible to support integrations with multiple sources – 4 • Put strong emphasis on usability – 3 • Ensure document security applies to integrations - 5
COPs	4 3.825 0.83	<ul style="list-style-type: none"> • Integration with existing collaboration tools – 8 • People and time constraints might prevent people from using this capability – 1
Metrics	5	<ul style="list-style-type: none"> • Knowledge quality is key, need to have quality mechanism and processes in place for

	4.35	the metrics to be meaningful – 9
	0.79	<ul style="list-style-type: none"> • Standardize metrics at the enterprise level to ensure “apples to apples” comparison- 6 • Should support user-defined metrics – 9 • Metrics need to account for different project types and other key distinguishing factors - 6

Table 7. *Questionnaire Results – Summary Section*

Additional capabilities or general design considerations	Number of responses
Ensuring clear definitions of relevant terms such as “knowledge” and “information” is key	2
Proposed sub-capability: require users to provide contextual knowledge when a change is made to a PPM entity	1

Table 8. *Questionnaire Results – Grand Means of Proposed Processes’ Ratings*

Parameter	Grand Mean
Process A (proposal evaluation) – grand mean of mean values assigned to this process’s capabilities	3.53
Process B (resource allocation) – grand mean of mean values assigned to this process’s capabilities	3.61
Process C (periodic performance review) –	3.97

grand mean of mean values assigned to this process's capabilities	
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Table 9. *Questionnaire Results – Grand Means of Proposed Capabilities' Ratings*

Parameter	Grand Mean
Contextual learning capabilities	4.21
Integration with knowledge repositories	3.11
COPs	3.53
Metrics	3.96

s

Table 10. *Questionnaire Results – Variation and Reliability Measures*

Parameter	Result
Mean standard deviation across all ratings of all capabilities	0.98
Pearson correlation coefficient of rankings of the three processes based on grand means of perceived value of KM for each process and grand means of all capabilities within each process.	0.64

Table 11. *Questionnaire Results – Grand Means of Overall Perceived Value*

Parameter	Grand Mean
Grand mean of mean values assigned to all capabilities	3.7

Summary of Findings and Interpretations

The questionnaire's results have been used to validate and enhance the proposed system design, and have been embedded in these sections. The bulleted list below outlines a summary of these findings, and their interpretations:

1. With a median of 8.5 years of experience in the field of PPM (9.82 mean), 37.5% authored PPM publications, and 60% holding an official PPM certification, the overall credibility of the respondents to participate in this study seems strong.
2. The mean Pearson correlation coefficient between the mean rating of each process's capabilities and the ratings assigned to the process directly is 0.64, representing a positive indication of internal consistency reliability.
3. The mean standard deviation across all ratings of all capabilities is 0.98, indicating a satisfactory low level of variation.
4. The overall perceived value of KMS for PPM, as measured through grand means of each capability's ratings (3.7) support the postulate of KM and KMS as a gap in contemporary PPM implementations.
5. The grand means of all three PPM processes which the KMS aims to empower, are above 3 and therefore in the range of "valuable" to "extremely valuable". Not a single respondent proposed application of KM to any other PPM process, indicating that the three proposed processes are likely to be the right ones. At the same time, the variance of grand mean ratings among the three is quite significant, which should influence their prioritization and allocations of resources in future studies.
6. Similarly, all grand means of the proposed capabilities across the three processes are above 3 as well, yet with significant differences among them. Contextual learning capabilities have scored by far the highest (4.21), consistent with one of the key principles of the situated learning theory, and some of the KMS studies covered in the literature review.
7. Integrations with knowledge repositories have scored the lowest (3.11). It is assumed that this relatively low rating is partially influenced by the status of each

respondent's organizational information systems. For example, the respondents which their organizations do not own external information systems with valuable PPM knowledge are assumed to be less likely to see the value in these capabilities. In general, environmental factors have a strong influence on requirements elicitation (Christel & Kang, 1992) and the other proposed capabilities are likely to have been influenced by specific organizational factors. However, they are confined within PPM and therefore less prone to this effect.

8. The respondents have outlined important design considerations, wherein some were not included in the original design, while others support it. The new design considerations have been validated and investigated based on a second literature review and then added to the original design. With the exception of two design considerations outlined by a single respondent, all the design considerations suggested reflect an understanding of the proposed capabilities which is a positive indication of face validity.
9. While trying to find repeating subjects among the design considerations suggested by the respondents, it was revealed that *knowledge quality*, and *system usability* dominate the list (32, 23 comments respectively), which should be kept in mind for future work in the area. While system usability is a critical factor in most systems involving user interaction, knowledge quality is more specific to KMS, and has been discussed in the design considerations and technologies sections.

Design Considerations

This section describes various design considerations defined as items with either certain or probable influence on the KMS design, based on academic and industry sources, as well as the questionnaire's responses. For each such design consideration, relevant literature is discussed, relationship to the KMS described, and different questions that need to be addressed as part of the KMS design are raised. Based on this discussion, recommendations for general attributes of the KMS are made. While this list only covers design considerations that are specific to KMS or KMS for PPM, more general

considerations that influence the design of almost any technical solution used by organizations, such as user interface design, clearly apply to future work in this area as well and should be taken into consideration.

Design Consideration #1: Integration of Expert Knowledge with local Knowledge Sharing

The design consideration of integrating expert knowledge with local knowledge was derived based on Markus, Majchrzak, and Gasser's (2002) seminal study in which they attempted to address the design problem of providing IT support for emerging knowledge processes (EKPs) of organization design. They defined EKP as: 1) An emergent process of deliberations with no best structure or sequence. 2) A process with complex knowledge requirements distributed across people and evolving dynamically. 3) A process with an unpredictable actor set in terms of job roles or prior knowledge. They suggested that EKPs require a new IS design theory based on a number of studies arguing that existing IT designs do not effectively support these processes on one hand and that there is great potential for organizations by using EKP-supported IS on the other hand (e.g. Davenport et al., 1996).

The design theory proposed by Markus, Majchrzak, and Gasser was created while they designed and deployed a system for the EKP of organization design, called "TOP Modeler". They have initially assumed that components of a traditional expert support system such as knowledge base, inference engine, and interface would promote a desired synthesis between expert and local knowledge input from different departments.

However, over the course of the project, they realized that users of different departments had very different perspectives on organizational design, and did not solicit input from other functional areas. Consequently, they recognized that components of a traditional expert support system were not enough, and that they had to incorporate system design features that would promote knowledge sharing among organizational members in different functional areas.

The importance of their study's conclusions to the KMS design is twofold. At a conceptual level, it highlighted the possibility of integrating expert and local knowledge in the KMS, which is applicable to PPM given the prevalence of organizational Program Management Offices (PMO) viewed as domain experts and thought leaders. Leading practices created by the organizational PPM experts organization, should be synergistically integrated with local PPM knowledge created during the execution of ongoing PPM processes. At a more technical level, the system design guidelines provided in their study should be taken into consideration in future studies that focus of more detailed KMS design and system development.

Design Consideration #2: Existing KM Solutions and Guidelines for related Domains

The literature review has not identified any comprehensive technology-based KM frameworks for PPM. Nevertheless, KM solutions and guidelines in overlapping, related, or subsumed knowledge domains have been proposed by different scholars and can be considered an important input to design of the KMS. Although concepts suggested in KMS studies in domains unrelated to PPM may be useful as well and should not be overlooked, the closer the knowledge domain is to PPM, the greater the likelihood of its usefulness to the studied questions.

One example of a closely-related knowledge domain is PM. It is a fundamental element of PPM, and considered a well-established academic and industry discipline with nearly six decades of research and practice. Although PPM naturally minds IT projects only, the view of leading professional PM organizations, such as the PMI, is that PM standards apply to *all* types of projects. Despite the well-established status of the PM discipline, the study of KM in project environments is still in its infancy. Nevertheless, several KM frameworks and guidelines for project environments have been proposed and two are described briefly below.

Ayas (1996) proposed a structural approach to PM learning based on organizational learning theory (Mills, 1992) and the social nature of situated, tacit

knowledge (Nonaka, 1991). She proposed a project network structure model utilizing social networks as a means of converting tacit knowledge to explicit knowledge among team members. She provided the following explanation for utilizing a network structure model: "the project network structure enables effective learning with project management because it enhances knowledge creation and improves the quality of information transfer within and between projects" (p. 1) In subsequent research, Ayas claimed that her model was proven successful in reducing the cost and schedule of product development projects (Ayas & Zeniuk, 2001).

Kasvi, Vartiainen, and Hailikari (2003) examined program and project KM frameworks utilized by the Finnish government and concluded that the observed KM practices were weak and unsystematic. Based on a series of interviews and questionnaires they proposed the following high level guidelines for KM in project environments: 1) Identify KM as a critical project competence. 2) Ensure the projects themselves are systematically managed as a pre-requisite for an effective KM. 3) Ensure that team members feel they gain personal benefit from experience documentation and perceive its utility (Landes & Schneider & Houdek; 1999). 4) Manage both substance and context knowledge throughout the whole project process. Although some of these guidelines have been repeated in other studies (e.g. Jullian, 2008), no study was found to test all four.

Design Consideration #3: Varying PPM Maturity Levels

Adoption of PPM approaches tends to be a long and gradual process. Different models for assessment of the PPM "maturity" level of organizations have been proposed by both industry organizations and PPM researchers (e.g. Berinato, 2001). In addition to helping organizations assess their current PPM maturity level, these models are also used by organizations to determine their PPM implementation road maps, with the aim of gradually climbing the maturity model.

Perhaps the most comprehensive and widely-cited PPM maturity model has been proposed by Jeffery & Leliveld (2004), based on the staged Capability Maturity Model

(CMM) for software development and developed at Carnegie Mellon's Software Engineering Institute (1993). The different stages and key characteristics of each stage included in the model are: 1) Stage zero: *ad hoc* – PPM decisions are made in an uncoordinated way. 2) Stage one: *defined* – key components of IT portfolios are identified and documented but there is no consistency in organization wide compliance, links into budgeting cycles and feedback loops to assess actual return. 3) Stage two: *managed* – standardized PPM processes exist and have a clear link with the organizational strategy; actual returns are consistently calculated but only reviewed annually. 4) Stage three: *synchronized* – investment portfolios are aligned with the organizational strategy, the portfolio is routinely assessed and decisions made accordingly.

Given the intent to design a generic KMS for PPM, the variance in PPM maturity levels across different organizations poses several challenges. First, different maturity levels may translate into different organizational KM needs and corresponding solution requirements. Second, since organizations tend to slowly climb the maturity model, the solution needs to accommodate this growth and be flexible and scalable enough. Third, PPM maturity models such as the one described above rarely perfectly match the reality in organizations. For example, organizations may be assessed as stage one for some PPM characteristics and be assessed as stage two for other characteristics, which dictates additional solution flexibility.

The KMS requirements stemmed by each characteristic in Jeffrey and Leliveld's model, as well as other credible knowledge sources, will need to be analyzed both individually and in relation to other characteristics in future studies. The flexibility and scalability of requirements dictated by the varying PPM maturity levels are likely to lead to highly *componentized* KMS (Markus, Majchrzak & Gasser's ,2002).

Design Consideration #4: PPM roles, Responsibilities and Skills

Another design consideration related to the previous one stems from the variance in roles, responsibilities, and skills across different PPM implementations. Although these three factors are influenced by the PPM maturity model, they are viewed as a separate design consideration for two reasons. First, these factors are also influenced by other factors than the PPM maturity level, such as the organizational structure. Second, PPM maturity models such as Jeffrey and Leliveld's are focused on *what* organizations at each maturity level do, not so much on *how* they do it, which is better articulated through these three factors.

For example, in Jeffrey and Lelivelds' PPM maturity assessment model, only the highest level of maturity involves tracking of project benefits after their completion, which requires knowledge of certain finance concepts. However, the organizational skills will help determine how well project benefits tracking are being done while roles and responsibilities will help determine by whom.

Since the intent of study paper is to facilitate propositions of generic KMS for PPM, the roles, skills, and responsibilities variance adds to the requirement mentioned in the previous section of designing a flexible solution, but also with respect to these three elements. The second type of solution flexibility is dictated by the fact that with or without any changes to an organization's PPM maturity level, roles, responsibilities and skills tend to be very dynamic in large corporations that implement reorganizations, workforce changes etc.

Design Consideration #5: Knowledge Management and Globalization

Cramton (2001) examined knowledge problems caused by the geographic barriers in a study that provides a good starting point for an impact analysis of the global nature of organizations on the KMS design. Cramton identified five types of mutual knowledge maintenance failures in such organizations: failure to communicate and retain contextual information, unevenly distributed information, difficulty communicating and understanding the salience of information, differences in speed of access to information,

and difficulty interpreting the meaning of silence. Cramton used Krauss and Fussell's (1990) definition of mutual knowledge as "knowledge that communicating parties share in common and know they share" (p. 346) and suggested that establishing mutual knowledge is important because it increases the likelihood that the communication will be understood.

These problems, coupled with the growing demands faced by such organizations, increase the reliance on technologies that are capable of mitigating them. Alavi and Leidner (2001) have therefore suggested that IT be intertwined with organizational KM processes and call for a greater scholarly interest in the use of IT for KM. One such example described in their review of KM conceptual foundations and research issues is that of British Petroleum, which uses video technologies to transfer offshore drilling knowledge its employees.

In the context of the aim of this study, these studies raise different topics for further investigation, related to the following issues: knowledge problems caused by geographic barriers that are specific to PPM; patterns of PPM implementations' geographical expansions; and internalization support of KM technologies.

Design Consideration #6: Integration of local and External Knowledge Sources

Integration with external knowledge sources is a popular topic in the KM literature with implications for the KMS for PPM. For example, Von Krogh, Nonaka, and Aben (2001) have demonstrated the potential value in integrating the organizational knowledge base with external knowledge sources, through a framework of four strategies for managing knowledge based on conceptualization about KM practices at Unilever, a multinational consumer goods company.

Two of these strategies involve integration with an external knowledge sources and will be briefly described. The KM strategy of *expansion* is aimed at increasing the scope and depth of knowledge by refining existing knowledge and by bringing in additional expertise relevant for knowledge creation. This expertise could come from

external sources such as partners or universities. They suggested that organizations can benefit from this strategy in the following ways: efficiency wise, it expands on quality related to existing processes; innovation wise, it helps create new process and product innovations from existing knowledge domains; risk wise, the further development of knowledge domains helps organizations reduce the risk of overtaxing resources, reduces the risk of deterioration, or regulatory non-compliance.

The second relevant KM strategy mentioned in their study is the *appropriation* strategy, which is predominantly an externally orientated strategy. Unlike the expansion strategy, which builds on an existing knowledge domain, the appropriation strategy is about building up a new knowledge domain through transfer of knowledge from external sources. They suggested that organizations can benefit from this strategy in the following ways: efficiency wise, transferring knowledge from an external source rather than creating it internally tends to be more resource effective; innovation wise, this strategy may be particularly powerful as the external source may provide knowledge that can provide a unique platform for building up new knowledge, products, and services internally; risk wise, the creation of the knowledge domain may help organizations reduce the risk of overtaxing resources, reduces the risk of deterioration, or regulatory non-compliance.

PPM adopted organizations may decide to follow the expansion or appropriation strategy depending on factors such as the overall organizational KM strategy, or their in-house PPM knowledge levels. Consequently, a KMS for PPM may be constructed to support electronic knowledge import from relevant PPM sources. Regardless of the strategy followed, it should be kept in mind that there are ample external PPM knowledge sources, which increase with the penetration level of this discipline.

For example, the Project Management Institute (PMI), periodically publish PPM standards and best practices that are widely adopted by organizations. The PMI standards, or standards of other credible professional organizations, may be used as solid basis for a new PPM knowledge domain in organizations that do not have such knowledge domain (appropriation strategy), or may add to an existing knowledge domain (expansion strategy). Other examples of valuable external knowledge sources include legislation that

has implications for PPM (e.g. Sarbanes-Oxley act of 2002), or knowledge from partners who collaboratively work with the organization on innovative projects.

Design Consideration #7: Personalization versus Codification KM Strategy

One prevalent classification of the approach organizations take for KM is of *personalization* or *codification* strategies (Hansen et al., 1999). Organizations that follow the codification strategy codify knowledge and store it in databases where it can be accessed by anyone. The aim of this strategy is to have organizations invest once in a knowledge asset and then reuse it multiple times, typically with the support of IT that helps connect people with codified knowledge.

Conversely, organizations that follow the personalization strategy focus on closely tying knowledge to the person who created it, and then sharing that knowledge through person-to-person communication. This strategy is typically employed in organizations that provide highly customized solutions to unique problems, which require creative and analytical advice. The role of KM in such organizations is to develop social networks so that knowledge can be shared. These processes may be supported by IT, although its role may not be as crucial as it is for the codification strategy.

Hansen et al. (1999) suggested that while most organizations employ both strategies, one is always more dominant than the other and organizations who try to put equal emphasis on both strategies fail. They further suggested several guidelines for selection of one strategy versus the other: the degree to which the organization produces standardized versus customized products; the reliance of people on explicit or tacit knowledge for problem solving; and whether the organization's products are mature or innovative in nature.

While considering their study in the context of the aim of this study, it clearly stimulates productive thoughts. However, one key difference to keep in mind is that the two strategies and guidelines for selecting one versus the other described in their study apply to the organization and its competitive strategy as a whole, and may be less

relevant for one specific knowledge domain that is more internally focused as PPM. For example, two of the selection guidelines mentioned above are related to the nature of the organization's products, and should probably not have a strong implication for selection of one strategy over the other for the PPM knowledge domain.

Some PPM processes, such as during the evaluation of technically complicated project proposal, the personalization strategy may seem more appropriate. On the other hand, for repeating PPM processes such as straightforward resource allocation, the codification strategy might be better suited. Therefore, an important question to be answered in future studies in the area is how this theory applies to specific knowledge domains that are not at the core of the company's business.

Furthermore, since the intent of this study is to facilitate the design of a generic KMS and different organizations put more emphasis on one strategy versus the other, different implications of this variance would need to be taken into account as well. For example, one important question is whether the existence of these two strategies should affect future solution designs in a way that calls for some of its elements to be specifically designed for organizations that follow the personalization or codification strategy.

Design Consideration #8: Exploration versus Exploitation of Knowledge.

Prior to the coinage of the term "Knowledge Management", March (1991) discussed the complicated relation between "*exploitation*" of old certainties and "*exploration*" of new possibilities in organizational learning (OL). March suggested that a trade-off relationship exists between these two processes, since organizations always lose something by allocating more resources to one versus the other. For example, a popular problem described in OL is the balancing between refinement of an existing technology and invention of a new one (Winter, 1971; Levinthal & March, 1981), where each option holds both advantages and disadvantages.

March suggested that finding the appropriate balance between exploration and exploitation is made particularly difficult as the same issues exist at levels of a nested system - at the individual level, organizational level, and social system level. Finally, he described two OL models as means of exemplifying the implications of the relation between exploration and exploitation on accumulation and utilization of knowledge in organizations.

The relation between exploitation and exploration in OL has been thoroughly studied since the publication of March's research and different studies examined the way in which organizations can influence it. One such study is Kane and Alavi's (2007) which examined how organizations may use IT-enabled learning mechanisms to affect the desired balance between the two processes through an extension of the computational model used by March (1991).

Their results showed that each of the examined IT-enabled learning mechanisms - knowledge repositories, groupware learning environments, and electronic COPs - has a distinct effect on the exploration and exploitation dynamics in OL. In addition, the use of these tools together, environmental conditions, and the learners' characteristics were found to influence these dynamics as well. Hence, they concluded that choosing the right IT-enabled learning mechanisms may yield a considerable benefit for OL.

These studies provide useful insights for this study. Since these two processes may manifest themselves in various technical forms, and since different adoption ratios between them appear in different organizations, the KMS for PPM should be flexible enough to effectively support different manifestations of this concept. Kane and Alavi's study provided information about the distinct and aggregate effect of specific IT tools and factors, which may be used as a solid starting point for incorporation of this concept into a detailed KMS design.

Design Consideration #9: Communities of Practice

The situated learning theory (Lave & Wenger, 1991), appears to be a sound learning theory to support potential PPM-focused KM solutions chiefly due to its strong association with KM and OL described in the literature review section, and the ratings of ECOP capabilities by the questionnaire's respondents (3.53/5 grand mean). This section takes the association between this theory and the present study to the next level by discussing different aspects of the relationship between COPs and KMS.

Von Krogh, Nonaka, and Aben (2001) demonstrated how the concept of COP can be fostered as part of a KM initiative and the potential value it yields. In their case study of Unilever Corporation, the company organized knowledge workshops that brought together key experts and practitioners in order to capture what the company knows and does not know in various functional areas. These workshops resulted in a shared vocabulary and terminology, initiation of COPs and identification of knowledge gaps. Each COP was then associated with a specific knowledge domain to which the COP participants contributed, and consisted of both explicit knowledge and a list of key people and groups with tacit knowledge. The purpose of these COPs was to nurture the sharing and creation of practices and knowledge by ensuring that professionals collaborate across different boundaries.

IT played an important role in the Unilever initiative, especially due to its ability to assist overcoming domain or geographical barriers. For example, collaborative computing applications allowed organizational members to form, organize and maintain their community interaction across geographical boundaries in a cost effective way. These applications, coupled with data storage and search capabilities, helped Unilever create knowledge repositories, which further facilitated knowledge sharing and knowledge value assessment. Unilever reported on various benefits gained by its implementation of the COP concept: quick identification of knowledge gaps, improved decision making, collaborative innovation across different boundaries, and rapid sharing of experiences and good proven practices.

Kane and Alavi (2007) examined the effect of three IT tools on OL through a computer simulation developed based on a well-studied company case study. One of

these examined tools was ECOP and their findings provide several useful data points for the KMS design.

First, ECOP was perceived by users as a lean KM mechanism, compared to the two others (knowledge repositories and groupware learning environments). They suggested that the explanation for this perception might be related to the differences in the amount of type of knowledge exchanged in ECOP compared to the two other tools.

Second, ECOPs were used for knowledge exchange regarding relatively specific and tacit issues, without the benefits of significant contextual or shared background knowledge. As different IT tools provide affordance to different types of knowledge sharing, different perceptions of richness of each tool are formed.

Third, ECOP was found to cultivate knowledge exploration by preserving knowledge heterogeneity. Knowledge levels under ECOP were found to increase more slowly than the two other IT tools, but did not plateau as the other tools have and eventually exceeded the observed knowledge levels of the other tools. This knowledge growth pattern was observed even under simulated environmental turbulence effects, which have caused degradation in the knowledge captured through the other tools. Nevertheless, their examination of concurrent use of ECOP with the two other tools revealed that the overall results of ECOP degrade when the two other tools, that foster knowledge exploitation, are added to the process. The explanation provided in their study was that homogenous knowledge provided by exploitation tools erodes the knowledge gains of ECOPs which rely on knowledge variance.

Alavi and Leidner (2001) outlined several important questions related to COPs and the role of IT. Perhaps the question with the strongest implication for potential PPM-focused KM solution is related to the influence of the strength of the ties within a COP on knowledge creation. Some researchers argue that close ties in a community limit knowledge creation, as its individuals tend to possess similar information. The holders of this view (e.g. Robertson et al., 1996) support the need of having weak ties in communities so that knowledge can be created through exposure to new ideas. On the other hand, other researchers (e.g. Brown & Duguid, 1998) argue that close ties in a

community actually better serve knowledge creation, as its members share a common language, and feel more comfortable discussing ideas openly. In light of these two views, Alavi and Leidner raised the question of whether IT can enhance knowledge creation by enabling weak ties among organizational members while reinforcing close ties in COPs.

These two objectives are applicable to PPM as well. First, certain aspects of the PPM work, such as the interaction among teams of practitioners, make it a potentially good environment for formation of COPs, although other factors such as the typical geographical disparity in large organizations may have an opposite effect. Therefore, fostering the formation and close ties within these COPs is a highly desired objective. Second, the transfer of knowledge among different projects has been proven to be instrumental (Durbin & Wheeler, 2002; Owen, Burstein, & Mitchell, 2004) and therefore enablement of weak ties among members of different projects may be situationally incorporated as well.

Design Consideration #11: Contextual Learning

The second key principle of the situated learning theory described in the literature review is that learning is "situated", as it takes place in the same context in which it is applied, and is a function of the activity and culture in which it occurs. The intent of future PPM-focused KM as described in is to enable such learning through technologies that facilitate contextual knowledge acquisition, which has also been supported by the questionnaire's responses (3.53/5 grand mean rating).

Davensport and Glaser (2002) suggested that the key to success of KMS is to "bake specialized knowledge into the jobs of highly skilled workers - to make the knowledge so readily accessible that it can't be avoided" (p. 2). They demonstrated their point through the case study of Partners Healthcare, a Boston-based umbrella organization that includes several hospitals and physicians' groups. The trigger for the development of the KM solution at Partners Healthcare was the enormous amount of knowledge related to the work of the physicians that made it virtually impossible for

them to absorb it all. This problem was literally a problem of life and death as an internal research found that five percent of patients had adverse reactions to drugs while under medical care, out of which more than half were caused by inappropriate drug prescriptions.

As a result, Partners decided to undertake an ambitious project to associate enormous amounts of constantly updated clinical knowledge to the IT systems that supported physicians' work processes. Their solution was built on a set of integrated IT systems that were used for management of patient care. All these IT systems drew from a single data repository of clinical information and used a shared logic engine that runs physicians' orders through a series of checks and decision rules. This solution was found to help physicians learn from other employees' experiences, access important information just-in-time, and reduce the number of serious errors by 55% overall. It also allowed the organization to quickly influence physicians' prescription-related decisions based on new knowledge that is believed to be valuable, such as a convincing new study.

Davensport and Glaser's study also suggested a number of keys to success for integration of contextual knowledge in work processes. While most of these recommendations are focused on organizational culture, and thus believed to be largely out-of-the scope for potential PPM-focused solutions, two of which are viewed as relevant and will be described. First, they suggested that since such initiatives tend to be highly complex, they should only be undertaken for truly critical knowledge work processes. Other selection criteria include knowledge processes with low levels of ambiguity, a well-established knowledge base, and low number of choices facing the decision makers. Second, given the criticality of the domain, they recommended having tight selection and control structures over the individuals who are allowed to maintain the knowledge repository.

Alavi and Leidner's (2001) four process framework for analysis of the role of IT in organizational KM described earlier – knowledge creation, storage/retrieval, transfer, and application – will be used to discuss implications for contextual knowledge.

One important consideration surrounding *knowledge creation* is how much context to include. In many cases, storing knowledge without sufficient contextual information will not result in effective uses, which could lead to the essence of the knowledge being lost (Zack 1998). Alavi and Leidner argued that the greater the shared knowledge space, the less context required for organizational members to share knowledge within the group. This, in turn, increases the value of explicit knowledge and the value of IT. Conversely, a smaller shared knowledge space increases the requirement for contextual information, and reduces the relevance of explicit knowledge and the role of IT .

From a *knowledge storage/retrieval* perspective, Alavi and Leidner suggested that IT can play an important role in the enhancement and expansion of both *semantic* (general, explicit, and articulated knowledge) and *episodic* (context-specific and situated knowledge) organizational memory, through technologies as search engines or multimedia databases.

From a *knowledge transfer* perspective, Alavi and Leidner noted that personal communication channels may be more effective for distribution of highly context-specific knowledge. Some of the research questions concerning knowledge transfer raised by Alavi and Leidner, which would need to be carefully considered in future studies in the area work include: 1) How can knowledge be effectively transferred among organizational units? 2) What organizational and technical strategies are effective in facilitating knowledge transfer? 3) Does the application of IT to knowledge transfer inadvertently discourage external searches for knowledge?

From a *knowledge application* perspective, Alavi and Leidner confirmed that knowledge can be embedded in organizational routines through the use of technology (similar to the example at the beginning of this section). However, they did raise a concern that this enforced knowledge application may cease to be useful and require technology modification when organizational conditions change. Therefore, organizational members are ought to remain attuned to contextual factors and consider the effect of current circumstances on enforced knowledge application .

These studies provide useful insights and lay out important questions to be answered as part of this study and future studies in the area. While it is clear that integration of context-based knowledge in certain PPM work processes is desired, Davensport and Glaser's recommendations to focus on a small number of work processes for contextual knowledge integration as well their selection criteria should be kept in mind while performing a detailed design of the KMS for PPM. Therefore, perhaps the first question that would need to be answered is which PPM processes to focus on for contextual knowledge integration. Other important questions, influenced by Alavi and Leinder's study, are the degree of contextual information to capture as well as a series of questions related to effective transfer of contextual knowledge.

Design Consideration #11: Existing PPM Software tools

Whether organizations use a software application for management of PPM processes and how they use it are important design considerations since KM solutions would need to integrate with existing digital data in a useful manner.

The need to use dedicated software for PPM is an issue of debate in the literature. While some believe that it is not needed at all, others view it as always indispensable and a third group views it as indispensable under certain conditions. For example, in Jeffrey and Leliveld's (2004) PPM maturity assessment model the use of PPM software is a characteristic of both of the lowest and the highest maturity levels. On the other hand, De Reyck et al. (2005) suggested, based on a survey of 125 companies, that implementing dedicated PPM software will not add any value unless all other major processes have also been adopted, and therefore should only be implemented by organizations at the highest level of adoption.

While the debate over the need to use dedicated software for PPM continues, the penetration rate of software tools for PPM is high and continues to increase based on the market research firm Gartner (2009). This fact, coupled with the belief that it would be valuable to have the potential KMS integrate with existing PPM data stored in a digital

format for many use cases, a design assumption that was made for this study and strongly influenced the solution design was that target organizations do use such software. While specific capabilities and implementation pattern of PPM software packages utilized by organizations will have an effect on the final KMS configuration, the KMS design proposed in this study has been intentionally kept highly generic in nature.

Design Consideration #12: Reach of the KM Solution

Another important consideration related to the user community is the reach of the KM solution, as measured by the size of the user group. The importance of this issue stems from an implicit trade-off relationship between the amount and relevance or usefulness of information (Hiltz & Turoff, 1985). KMS limited to a small group of users are likely to gather highly useful and relevant information but lose valuable input that may be obtained from a broader group. Conversely, when the reach of the system is too broad, it holds the risk of irrelevant information overload.

While this trade-off relationship is generally true, (Hahn & Subramani, 2000) have suggested that the effect of the size strongly depends on the *type* of knowledge sources. For example, when the knowledge sources are artifacts such as methodology documents, size may have a positive network effect, especially given the sophistication level of contemporary search engines. However, when the knowledge sources are more individual in nature, such as electronic discussion forums, size may have negative network effects. For example, an oversized discussion forum may lead to concurrent threads of conversations, making it more difficult to follow and participate in discussions (Kerr & Hiltz, 1982). On the other hand, an undersized discussion forum may not offer sufficient resources to make the participation beneficial.

The size of the user base consideration has important implications for the *implementation* of the solution, such as system rollout planning, that go beyond the scope of this work. Nevertheless, this consideration may also affect the design of the solution in several ways. First, there may be a need for system capabilities that technically *limit* the

use of certain elements to selected groups or individuals. Second, there may be a need to *monitor* the number of users who use each element, as basis for decision making related to the implementation of the tool. Third, the underlying architecture of the solution as well as end-user functionality need to be able to handle a potentially large number of users and knowledge sources, such as advanced search capabilities.

Design Consideration #13: Design for Change

Unlike most traditional information systems, with KMS it is difficult to know in advance what kind of information will be requested, by whom, and for what purpose. Furthermore, the objectives and desired outcomes of KMS implementations tend to more subjective and heterogeneous with respect to different user views (Hahn & Subramani, 2000). These characteristics of KMS implementations make the development of requirements for KMS very difficult on one hand, and increase the likelihood of frequent system changes on the other hand.

On the PPM side, implementations tend to be highly dynamic in nature which can be attributed to several primary reasons. First, the relatively young age of this discipline leads to new findings and creation of domain knowledge cascading into organizations which adopted this discipline. Second, as organizations climb the PPM maturity ladder, new requirements and system changes are made necessary. Third, PPM implementations tend to be strongly affected by organizational changes such as mergers, acquisitions, or internal re-organizations. As the core PPM processes change as part of this dynamic nature, associated KM processes will often need to change as well.

Based on the above, it is clear that the KMS must be flexible in nature and supportive of an evolutionary system development approach in order to be able to address changing requirements and usage patterns in an effective manner. This need manifest itself in various system requirements from the KMS.

First, there need to be effective usage monitoring capabilities, able to answer the critical questions of whom and how do users actually the solution. These technical

capabilities should supplement non-technical approaches for system evaluation such as surveys and interviews, which should provide a fairly accurate picture combined. Second, the solution must be developed in a highly generic fashion reflective of an assumption of frequent changes. Third, to the extent possible, the solution should contain capabilities that allow standard users to personalize it to their needs, rather than relying on system changes performed by the technical team.

From a technical architecture perspective, designing systems for change is a broad and complicated subject that has been extensively researched in the discipline of software engineering. While an in-depth discussion of this subject goes beyond the scope of this research, two of the key principles that dominate the software engineering will be briefly described based on an influential study by Parnas (1979) that, although over 30 years old, is still highly applicable to contemporary software.

First, the concept of *generality* calls for design of software with limited restrictions and limitations, that is likely to be able to accommodate changing requirements with minimal or no changes to the underlying code. A well-known example of lack of software generality that led to an enormous effort is the "bug 2000" problem, wherein many software products were not designed to capture four digits for representation of the year. While generality of software is largely desired, Parnas suggested that sometimes lack of generality is necessary in order to meet the system's performance or cost requirements. In other words, there is a trade-off relationship between generality and other desired aspects of software.

Second, the concept of *information hiding* or *encapsulation* calls for isolation between the components that are likely to change and those that are not, and development of interfaces that connect these two types of components. When implemented correctly, the programs that use the changeable components through the interfaces are only able to access certain aspects of them, and there is no reason for the changeable components to know how many other programs use them. Therefore, when the changeable components change, the programs that use them need to change as well, often referred to as "loose coupling".

Design Consideration #14: Knowledge Quality

One of the two dominating design considerations outlined by the questionnaire's respondents was related to knowledge quality (32 comments). They have repeatedly emphasized that it is critical to maintain a high degree of knowledge quality in the KMS solution in order to meet its intended objectives of organizational learning and growth, similar to the widely-cited definition of high data quality "if they are fit for their intended uses in operations, decision making and planning" (Juran & Godfrey, 1999, p. 2.2).

While some of the design considerations described earlier, such as the system's reach or contextual learning, certainly affect the degree of knowledge quality, the aim of this section is to address this subject in more direct and holistic fashions. Maintaining a high degree of knowledge quality entails a lot more than an effective system design as it is influenced by numerous organizational, cultural, and human factors. However, given the scope of this work, the emphasis will primarily be on the former and different relevant issues, and approaches discussed.

Jennex (2008, p. 41) suggested that "knowledge quality ensures that the right knowledge with sufficient context is captured and available for the right users at the right time". Knowledge quality, in Jennex's view, has three constructs: 1) The KM strategy/process construct focuses on the organizational process for identifying knowledge users and the format/context of knowledge to capture. 2) The richness construct reflects the accuracy and timeliness of the stored knowledge as well as possession of sufficient knowledge and cultural contexts to make the knowledge useful. 3) The linkages construct reflects that availability of effective linkages to the captured knowledge, through such means as knowledge maps.

While these three constructs appear to be a solid framework, they will not ensure knowledge quality without a set of dedicated processes and techniques for improvement of knowledge quality captured in the KMS's repository. For example, Patton (2001)

specifically focused on knowledge quality of "lessons learned", a prevalent type of knowledge source in KMS, and proposed ways of enhancing their quality.

Patton suggested that high-quality lessons learned represent principles inferred from multiple sources which their internal validity is judged and then *triangulated* to increase transferability and generalizability of the knowledge. Only when a given source passes these tests, does its designation as a high-quality lesson learned or triangulated better practice, become appropriate. The confidence level in the significance and meaningfulness of a "lesson learned" increases based on the number of triangulation of supporting sources, and Patton recommended considering a lesson learned with only one type of supporting evidence as "lesson learned hypothesis".

Lim, Pervaiz, and Zairi (1999) argued that high quality knowledge repository can only be achieved with a considerable investment in humans, although IT can help. For example, Alavi and Leidner (2001) suggested that IT may increase the quality of knowledge creation by providing an effective forum through such means as collaborative capabilities. At the same time, IT may enable evaluation of the quality of knowledge after it has been created. Several such methods include: peer review system whereas users anonymously rate the quality of the knowledge sources of their peers, structured process according to which domain experts evaluate new knowledge sources and serve as "gate keepers" of the knowledge repository (O'Leary, 1998), and the use of technology to recommend on knowledge sources which seem to be irrelevant and therefore candidates for removal.

Alavi and Leidner (2001) have summarized this subject by pointing out key issues pertaining to knowledge quality in KMS: how to protect coded knowledge, what kinds of knowledge and at what level of detail can it be usefully codified, and how to ensure maintenance of knowledge. These questions would need to be discussed in the context of the KMS for PPM, as well as specific technological tools that may serve as effective enablers of knowledge quality.

Technologies

Overview

The technologies section used the design considerations and capabilities described earlier as an input to proposition of KM technologies which may be employed in their support. For each KM technology described below, answers or at least guidelines are provided for different related questions raised in the design considerations section, supported by the literature and the questionnaire's responses. Given the pace of technological change, this section avoids references to names of specific technological tools but instead focuses more on their core concepts and how they relate to the KMS.

System Integration Capabilities

A comprehensive KMS enables users to access other relevant organizational data and knowledge sources (Bowman, 2002), since organizational knowledge domains are rarely independent of others. This general sentence certainly applies to the domain of PPM as well, given its breadth and points of intersection with other organizational disciplines such as finance, human resources, or asset management. Indeed, many organizations construct integrations between PPM systems and external systems used to manage related domains (Gartner, 2010). Similarly, the KMS for PPM needs to contain integration capabilities with both KM repositories of those external systems and their transactional data, which has also been supported by the respondents (grand mean rating 3.11/5). These integration capabilities may empower users of the KMS for PPM as they create, capture, transfer, and apply knowledge by basing it on external sources when applicable, and potentially empower users of the integrated KMS as well.

This section contains an overview of IT system integrations followed by specific recommendations for KMS for PPM. Since system integrations are very organization-

specific as they depend on such variables as the IT system landscape, these recommendations are naturally less specific than for the other technologies recommended below.

A popular approach for organizational KM is to offer employees a single interface for all the organizational knowledge captured electronically (Bowman, 2002), often called a "Knowledge Portal". However, even when such an approach is taken, there is still a need for local knowledge storage in each system that feeds the organizational knowledge portal, hence this centralized approach complements and not replaces KMS of individual domains. In support of this claim, five of the questionnaire respondents have indicated that a system integration between PPM and an enterprise portal would be very useful.

From an end-users' perspective, maintaining a consistent user interface for PPM and its KMS is highly desired given the importance of contextual learning discussed earlier, and given the improved chances of users making an effective use of the KMS if its capabilities are conveniently available as they perform their PPM work. Technically speaking, the development, maintenance, and ability to apply system changes are to be drastically easier if the KMS for PPM and the PPM system itself adhere to the same underlying technologies, naming conventions, supported platforms, and architecture.

Constructing integrations between systems is one of the biggest challenges faced by modern IT departments, mostly due to heterogeneity of platforms, data privacy concerns, and frequent system changes which affect their integrations as well. Nevertheless, since they are so critical, most IT departments take on this challenge with varying levels of success depending on factors such as system complexity, degree of platform standardization, skill level of staff, complexity of integration requirements, and stability level the IT infrastructure in general. Given the challenges associated with system integrations, in most cases it is recommended to deploy a new system independently, gain initial traction, and only then tackle integrations. This same recommendation applies to integration of the KMS for PPM, other than the integration to the core PPM system itself.

Given the complexity level of system integrations, it is highly recommended to perform thorough analysis and design prior to any execution of any technical work. Key questions to be answered during these phases include: 1) What are the knowledge needs of the system that cannot or should not be maintained internally? 2) What are the external systems containing relevant knowledge? For example, in the domain of PPM such external systems may be financial, organizational strategy, IT asset management, human resources, or quality assurance applications. 3) What are the quality levels and other attributes of the identified knowledge in each external system? 4) How valuable, in absolute and relative terms, is it to import knowledge from each external system identified? 5) How frequently does the data need to be exchanged? 6) What are the planned changes for each identified external system and the IT strategy as a whole that could affect system integrations?

Similarly, owners of external systems that relate to PPM would need to answer the same questions since there might also be a need to *export* knowledge out of the KMS for PPM into their systems. Hence, at the end of this analysis and design phase, organizations are likely to classify the integration scenarios between KMS for PPM and related systems into three categories: 1) Bi-directional integrations between the KMS for PPM and external systems. 2) Unidirectional integrations 3) Situations where system integrations are not valuable to construct.

Listed below is a series of system recommendations for system integrations, some of which specific to PPM, while others are more general:

- 1) If possible, utilize the existing system integration approach used by the core PPM system.
- 2) Utilize open standard technologies for the actual implementation of the system connectors that are language/platform-independent, and enable loose coupling between the integrated systems.
- 3) Maintain a consistent approach for all the system integrations constructed.
- 4) Design for change given the likelihood of changes to the underlying systems.
- 5) Make use of robust industry “middleware” solutions that facilitate system integrations, rather than “reinventing the wheel” (10 comments on the

questionnaire). Typical capabilities of such solutions include a scheduling engine for the integration process, connectors to various data sources, and built-in data manipulation capabilities.

- 6) Ensure that every knowledge domain has a single *source application*, clearly communicate it to the user base, and always display the name of the source system with the external knowledge.
- 7) Do not perform more frequent data exchanges than the functional requirements dictate.
- 8) Ensure document security applies to integrations (11 comments on the questionnaire).
- 9) Put strong emphasis on usability – knowledge pulled out of external system needs to be presented in an intuitive fashion (8 comments on the questionnaire).

Knowledge Directories

Research suggests that there are two main models for KMS (Alavi & Leidner, 1999): the network model, that utilizes IT to connect knowledge owners with knowledge seekers and is particularly useful for providing access tacit knowledge and represents a belief in personalized knowledge; and the repository model that utilizes IT to store and transfer explicit organizational knowledge, and represents a belief in codified knowledge.

These two models are not mutually exclusive (Bowman, 2002) as organizations may pursue a KMS strategy focused on both explicit and tacit knowledge and therefore follow both models concurrently. For example, a knowledge seeker performing a search in a certain area may be presented with both a list of knowledge owners in this area but also with knowledge artifacts stored in a repository. The main technology used by organizations that follow the network model is knowledge directories also known as mapping of internal expertise, or “yellow pages” of experts.

Implementation of knowledge directories involves definition of knowledge categories relevant to the domain of the KMS, identifying and linking knowledge owners

to each such category, and creating a searchable directory to help knowledge seekers locate the right knowledge owners who might be able to help them. In other words, knowledge directories are not repositories of knowledge but rather gateways to knowledge. Once a connection is made between the knowledge seeker and the expert, the knowledge transfer occurs, which often involves *externalization* of knowledge – conversion of tacit to explicit knowledge (Nonaka, 1995).

The knowledge directories technology is applicable to PPM, especially during the process of evaluation of project proposals, in which expertise in different areas is required in order to determine whether to approve or decline the open ideas. Most PPM systems capture information about resources and the skills they possess, which may be useful for knowledge seekers in some cases, although skills in PPM are usually limited to skills required for execution of projects. In addition, knowledge seekers with very specific knowledge needs would normally find skill definitions in PPM too broad to help them find the specific person(s) with the knowledge they need. Therefore, although carry some KM value, typical skill databases do not eliminate the need to have knowledge directories in PPM.

Definition of the right knowledge categories is essential for users to be able to find the right knowledge owners. While there are software tools that analyze repositories of data and suggest certain knowledge categories, they might not be highly beneficial for PPM, which is a broad domain but not broad enough to justify the use of such technologies. Instead, the KMS should contain an initial set of default knowledge categories which apply to most organizations, and an interface that allows authorized users to edit knowledge categories and associate users with them.

In addition, it would be useful to be able to associate knowledge source with the same categories in order to enable functionalities such as the one described above of search that retrieves knowledge supportive of both the network and repository models. Beyond that, whenever a user reviews a knowledge source, the KMS needs to automatically display a list of knowledge owners for the knowledge categories associated with the document, in order to make the expertise highly accessible when needed.

Nevertheless, maintaining a list of knowledge categories that is right for the organization will not yield much value to knowledge seekers if the user records are not maintained up to date based on the latest list of knowledge categories and areas of expertise. This could be achieved through a combination of managerial and technical capabilities, such as automated reminders to users every reasonable interval. In order to make the knowledge search more effective, the KMS should also allow users to specify their proficiency level in each area of expertise based on a well-defined scale, and allow for entry of open text representing their experience.

Once a knowledge seeker finds the person who possesses the knowledge he is after, they can communicate through different media, such as phone, email, or even in person if they are located in the same physical location. Nevertheless, the KMS should enable communication through the system itself and users should be encouraged to utilize this interface rather than system external methods, for a number of different reasons.

First, it would enable storage of the knowledge transferred in a repository that automatically indexes it and enables it to be retrieved through the KMS's search engine, which would expedite the access the knowledge and reduce the risk of "overtaxing" knowledge owners. Second, it would allow other knowledge owners to participate, and further assist the knowledge seeker. Third, it would enable the KMS to capture the responsiveness of each knowledge owner to knowledge seeker, which can be used for different purposes.

Finally, since knowledge directories are a popular feature in KMS and since knowledge domains in organizations are so interrelated, it would be advantageous to centralize some of these capabilities. For example, there should be a single user interface for users to define their areas of expertise, rather than defining it separately in each organizational KMS. Handling knowledge directories holistically would require some degree of standardization, and construction of system integrations, yet will yield strong results if done right.

Contextual Learning Capabilities

The importance of contextual learning for KM and OL, relationship to the situated learning theory, and relevance to PPM have been discussed in the design considerations section. This section translates this discussion into practical ideas for incorporation of contextual learning capabilities into the system's design, supported by the questionnaire's responses.

Davensport and Glaser (2002) have suggested that integration of contextual knowledge in work processes should only be undertaken for truly critical knowledge work processes. These processes should be characterized with low level of ambiguity, a well-established knowledge base, and low number of choices facing the decision makers.

While connecting this recommendation to PPM, three such critical processes have been identified and the value of incorporating contextual knowledge into them has been strongly validated by the questionnaire's respondents: KM tied to evaluation, selection, and prioritization of proposals for projects or programs (4/5 median rating); KM tied to allocation of resources for approved projects and programs, and communication of portfolio decisions and expected outcomes to key stakeholders (4/5 median rating); and KM tied to periodic performance reviews of projects and programs (5/5 median rating). For each such process, certain steps need to be identified in which users are displayed with previously created knowledge.

In order to identify these steps, a thorough analysis needs to be performed, which can be facilitated by answering the following key questions: 1) What would a person need to know in order to complete this process? 2) At what point(s) in the process does the knowledge need to be applied? 3) What is the likelihood that the person wouldn't possess the required knowledge? 4) What is the likelihood that the missing knowledge is captured in the knowledge repository? 5) What is the likelihood of being able to retrieve the missing knowledge out of the knowledge repository in a way that would closely match the context in which it is sought?

While knowledge quality as a whole was covered in a separate section, some specific considerations specifically apply to contextual learning. One of the key considerations is how much context to include in order to make the knowledge valuable just-in-time (Alavi & Leidner, 2001). The questionnaire's respondents have emphasized the importance of this point by stating that display of knowledge that is truly related to the context is important in order not to overwhelm users (7 comments). Furthermore, five of the questionnaire's respondents have suggested that ensuring standardized terms is key for these capabilities to be effective.

On the other hand, it is important not to capture excessive contextual information to a degree that would make the previous knowledge captured available just-in-time in very limited scenarios, especially in early stages of the KMS implementation when the size of the knowledge repository is limited. Similar to the way many search engines operate, it is further recommended to include a "relevance" score for each knowledge source automatically retrieved by the system as an important productivity enhancer.

In addition to the use of contextual IT capabilities for knowledge transfer, the KMS should also utilize these capabilities for knowledge storage. For example, at a point where a final determination is made for project proposals, users should be required by the KMS to capture lessons learned during the execution of this process. Alternatively, one of the questionnaire's respondents suggested to have the system require users to enter contextual information upon *change* to one of the key attributes of PPM entities.

Requiring users to store data in specific contexts would not only increase the size of the knowledge repository, but also increase the quality as the knowledge is captured while it is still "fresh" in people's minds. This ability to publish knowledge contextually, as suggested by four of the questionnaire's respondents, should be role-based hence increasing the odds of capturing high knowledge quality.

Alavi and Leidner (2001) suggested that IT can help with the process of knowledge application through embedment in work routines. Core PPM processes are usually implemented through robust workflow capabilities, making these opportunities technically feasible. Therefore, it is recommended for organizations who implement

contextual knowledge capabilities as described above to periodically review the contextual knowledge associated with each step and the outcome decisions in an attempt to find “hard rules” that could be baked into the process.

When such rules are automated this way, it is important to make the users aware of the reasons behind the system’s automated response, so that this knowledge is retained in people’s minds. If implemented correctly, organizations can expect not only better outcomes from execution of these processes but also greater agility thanks to these automations.

Since embedding contextual knowledge capabilities into work processes is a complicated and involves a significant investment, measuring the effectiveness of these capabilities is particularly important. For example, metrics which may be used for measurement include the percentage of times the contextual knowledge is actually used, and correlations between these instances and the outcome decisions. Analysis of these metrics may result in system changes, such as different process steps that support these capabilities, or changes to the knowledge repository such as directed efforts to increase the knowledge captured for specific categories.

Electronic Communities of Practice

As described in the design consideration section, the concept of COPs has proven to be highly applicable to KM, and the nature of the PPM work is well suited for formation of COPs as originally assumed and later supported by the questionnaire's responses (3.53/5 grand mean). This section includes some specific recommendations for implementation of this concept in a KMS for PPM, starting with core and basic to advanced capabilities.

Core capabilities of ECOPs, which should also be supported in the KMS for PPM, include: creating, inviting users, and joining active ECOPs; posting messages through various media; storing and indexing members’ messages; providing the ability to access old messages; and be notified when new messages are added. Since different

organizational IT systems may support the ECOP functionality, and organizations may have well established internal knowledge exchange technologies, such as wikis or instant messaging, it is recommended to consider the possibility of integrating with these existing capabilities rather than constructing standalone ECOP functionality for PPM (25 comments on the questionnaire).

Dubé, Bourshis, and Jacob (2006) pointed out that the level of comfort members feel towards the use of ICT is an important consideration affecting the effectiveness of ECOPs, as lack of ICT experience may prevent some members from participating. The same consideration holds true for the KMS in general, although it is of greater importance for ECOP given the technical expectations and exposure level of each member's technical proficiency to the other community members. While attitudes towards ICT and proficiency levels can be addressed from different technological and non-technological angles, from a KMS design standpoint it calls for a strong emphasis on usability and support for different communications mechanisms such as whiteboards, videoconferencing, and instant messaging.

However, availability of an array of "meeting opportunities" may improve the levels of participation and quality of knowledge exchange (Barrett et al., 2004) even in situations where ICT's comfort level is not an issue. Different media may be suited for certain types of messages based their attributes (Daft, Lengel, & Trevino, 1987) enabling ECOP members to select the best fit medium for their messages. Specifically for PPM, since the number of concurrent system users tends to be quite low and since the geographic dispersion level of members is often high, synchronous technologies should be assigned a lower priority compared to asynchronous technologies.

In general, "weak ties" in organizations increase the breadth of knowledge sharing (Alavi & Leidner, 2001) and improve the chances for formation of COPs. While increasing weak ties in organizations usually involves non-IT activities such as face to face meetings, IT holds a promise for advancing this goal and so as a KMS for PPM. Some examples of such capabilities include: 1) Capturing and displaying the names and additional relevant information of knowledge source creators together with the actual sources 2) Recognizing top contributors to the knowledge repository through periodic

email notifications or system reports 3) Support for “affinity group filtering” technique (Bowman, 2002) according to which users define their topics of interests and automatically presented with the names of other users with similar interests.

Alavi and Leidner have also suggested that once the COPs are formed, close ties in the communities serve knowledge creation which IT should therefore reinforce. Some examples of such IT capabilities which the KMS for PPM should support include: ability to hold one-on-one conversations within the ECOP; ability of community members to follow the postings of other members of choice and be automatically notified when they post new items; and ability to create and access user profile pages of members containing professional and perhaps some personal information; and integration with other organizational collaboration tools.

Neus (2001) produced a set of recommendations for enhancing the quality levels of the knowledge exchanged in ECOPs, with relevance to the KMS design. First, ensuring members' accountability by saving the identity of the contributor and contents of the messages enables members to "screen" postings based on the past quality of contributions of each member and facilitate knowledge exchange. Second, having clear rules of the behavior and quality levels expected from ECOP members improves the information quality through peer pressure.

Once organizations have drafted such a charter, it should be displayed upon logon to the ECOP capabilities. Third, establishing criteria for membership in ECOPs is recommended as means of ensuring both focus and quality of contributions. While this recommendation is largely effective, given the relatively low number of participants in PPM, it is recommended, at least initially, not to set rigid membership criteria but rather let communities develop independently while monitoring their activity.

Knowledge Repository

Based on an analysis of the design considerations and desired capabilities of the KMS for PPM, it is clear that it needs to contain a robust knowledge repository that captures, processes, analyzes, and reports on explicit knowledge sources accumulated by the organization. While knowledge created through technologies described earlier is to be managed in a knowledge repository as well, this section suggests requirements pertaining to the repository as whole rather than to specific capabilities that use it for their operations.

A critical requirement is that the knowledge repository needs to be *centralized* – all the knowledge should be captured in a single database. Fortunately, modern databases are both capable of storing various formats of data, such as images, documents, or hierarchical data, and also capable of storing enormous amounts of data. Using a centralized repository holds many benefits such as the ability to retrieve all captured forms of knowledge for a given query, faster system development, efficient use of computer resources, easier maintenance, and improved ability to use consistent terminology. On the other hand, the centralized repository approach increases the risks of temporary inaccessibility to stored knowledge or complete data loss, and therefore must be accompanied with robust availability and disaster recovery capabilities.

Another key attribute of the knowledge repository is the ability to perform effective search of all the data captured in the repository, whether initiated by users or by the KMS for its internal operations. At a basic level, the search function should support Boolean searches based on various attributes of the knowledge sources, such as the ability to retrieve all the knowledge sources, whether text or multimedia, created by a certain user between certain dates.

At a more advanced level, the search function should include the ability to support fuzzy logic that retrieves data that is *mostly* true for a search term, and may contain relevant information. For example, a user seeking knowledge on a specific area should be presented with previously captured knowledge sources that either perfectly match his search or contains knowledge of similar areas, ranked based on their relevance.

One of the keys to an effective search function is proper indexing of the knowledge sources, and the recommended approach is a hybrid manual and automated approach. With this approach, users are asked to manually enter knowledge categories and key words the source is associated with, if not obvious from the context of knowledge creation, and at the same time have the repository automatically glean key words out of the source.

A critical element of a search function is the ability to display the search results in an intuitive fashion that eases the access to best-fit knowledge sources found for the search criteria. One approach for solving this problem in KMS is to cluster the search results based on knowledge category, content type, creator, and other fields. A common tool for this purpose in KMS is a knowledge map, which involves locating knowledge in the organization and publishing a graphical object that shows where to find it (Davenport & Prusak 1998). While a powerful tool if implemented correctly, the relatively low amount of knowledge typically stored in PPM does not justify the use of knowledge maps for the PPM knowledge domain alone.

Beyond the ability to effectively search for knowledge previously created by users, the knowledge repository should also help with the *creation* of knowledge. At a basic level, system reports that pull information out of the knowledge repository based on end-user preferences normally help in supporting peoples' thinking and lead to digital capture of their knowledge. At a more advanced level, technologies such as data mining can sometimes enable creation of completely new knowledge by identifying patterns and relationships not known before.

These technologies should be based on a set of pre-defined analyses, standardized across the organization (20 comments on the questionnaire), and cognizant of key distinguishing factors among PPM entities such as project type (13 comments on the questionnaire). Finally, the KMS should also allow users to mine the data and perform their analyses of interest in a flexible manner (22 comments on the questionnaire).

Different users have different knowledge interests and needs. In order for the repository to effectively support KM processes of creation, storage, transfer, and

application of knowledge it must support high degrees of personalization. In modern IT system, personalization manifests itself through a variety of capabilities such as automated reporting based on user's interests, and email notifications to users upon changes to relevant knowledge, also known as “standing queries” (Bowman, 2002). Users should have the ability to edit their list of knowledge interests and the system capable of applying this change to the knowledge exposed to them instantaneously.

The knowledge repository should further contain performance and utilization monitoring capabilities that will serve as objective and quantitative feedback loops of the solution. Some of these capabilities include: 1) Monitoring the system activity of specific users or pre-defined groups of users. 2) Identifying usage trends. 3) Assessing the usage levels of specific elements of the solution. 4) Identifying top contributors to the repository. 5) Identifying popularity of each knowledge category defined by the organization. 6) Assessing the system’s response time.

These metrics can help organizations implementing the KMS in various ways, including: 1) Use as basis for evaluation of the design of the solution 2) Identify user adoption issues 3) Recognize top contributors 4) Identify necessary changes to the knowledge categories defined. 5) Identify system performance bottlenecks that may be negatively affecting the user adoption.

It is critical to maintain high degree of knowledge quality in the KMS solution in order to meet its intended objectives and the issues pertaining to knowledge quality in KMS pointed out earlier (Alavi & Leidner, 2001) will be used as a framework for recommendations: how to protect coded knowledge, what kinds of knowledge and at what level of detail can it be usefully codified, and how to ensure maintenance of knowledge. While maintaining knowledge security in PPM is important, as an internal application it tends not be one of the major aspects of PPM implementations.

Nevertheless, often times highly confidential internal projects are being managed in PPM and proposals for organizational changes are submitted which need to be restricted to a small group of stakeholders, inclusive of the knowledge produced during their execution. Hence, having the ability to authenticate users, set access restrictions to

knowledge sources at different levels, create security groups of users, and audit user transactions is critical.

As far as the kinds of knowledge and level of detail that can usefully be codified, an evolutionary approach that provides users with a high degree of flexibility but at the same time closely monitors the KMS usefulness, is preferred. Alavi and Leidner (2001) provided several examples of metrics for evaluation of the KMS usefulness such as ratios between the available knowledge and knowledge accessed, and number of searches yielding results used by the users. Some of these metrics can be technically calculated by the system and should therefore be incorporated as system capabilities.

Similarly, certain technical capabilities may facilitate maintenance of knowledge. First, associating and displaying the creation and last update dates of each knowledge source may help in "flagging" knowledge that needs to be updated, although an old last update date of a certain source does not necessarily imply that it requires updates. Second, having the KMS display related knowledge sources upon creation of new sources may help identify existing knowledge sources that require maintenance. Third, providing an easy way for users to view all the knowledge sources created by them may serve as an effective reminder of necessary updates.

Entities Relationship Model

Overview

This section illustrates the way by which the key aspects of the KMS discussed earlier translate into conceptual system entities and their interrelations. In order to fulfill this goal, the Entity relationship model (ERM) has been employed, chiefly due to its prevalence and intuitiveness. Researchers and practitioners who wish to take this study to the next level of more concrete design and system development, may utilize it as a starting point.

The ERM, originally proposed by Peter Chen (1976), is a highly prevalent database modeling method used for system analysis and design. It utilizes diagrams called entity relationship diagrams (ERD) to represent the key entities of a system and the relationships among them, in abstract and conceptual fashions. ERMs support top-down system analysis strategies, whereas the ERDs of a given system are gradually decomposed into more concrete logical data model, up to the point where they can be used by developers to construct the system.

The ERM contains three building blocks - entities, relationships, and optionally attributes, to represent the system's conceptual model. An entity, per Chen, is a "thing" in the real world which be distinctly identified, such as a physical object or an event. A relationship is an association among entities such as a "house and roof", usually represented as a verb connecting two or more nouns. In addition, relationships may include certain cardinality constraints: one-to-one, one-to-many, and many-to-many. Both entities and relationships can have attributes that help characterize them. ERDs do not display specific instances of these three building blocks but rather sets of entities, relationships, and attributes.

While different ERD representations have been proposed throughout the years, this study used the version of the Unified Modeling Language (UML) for its popularity. The diagram contains two following elements: rectangles for representation of entities, and lines for representation of relationships inclusive of labels above them representing their nature and the cardinalities on the sides.

Entity Relationship Diagram of the KMS

Figure 2. Entity Relationship Diagram of the KMS

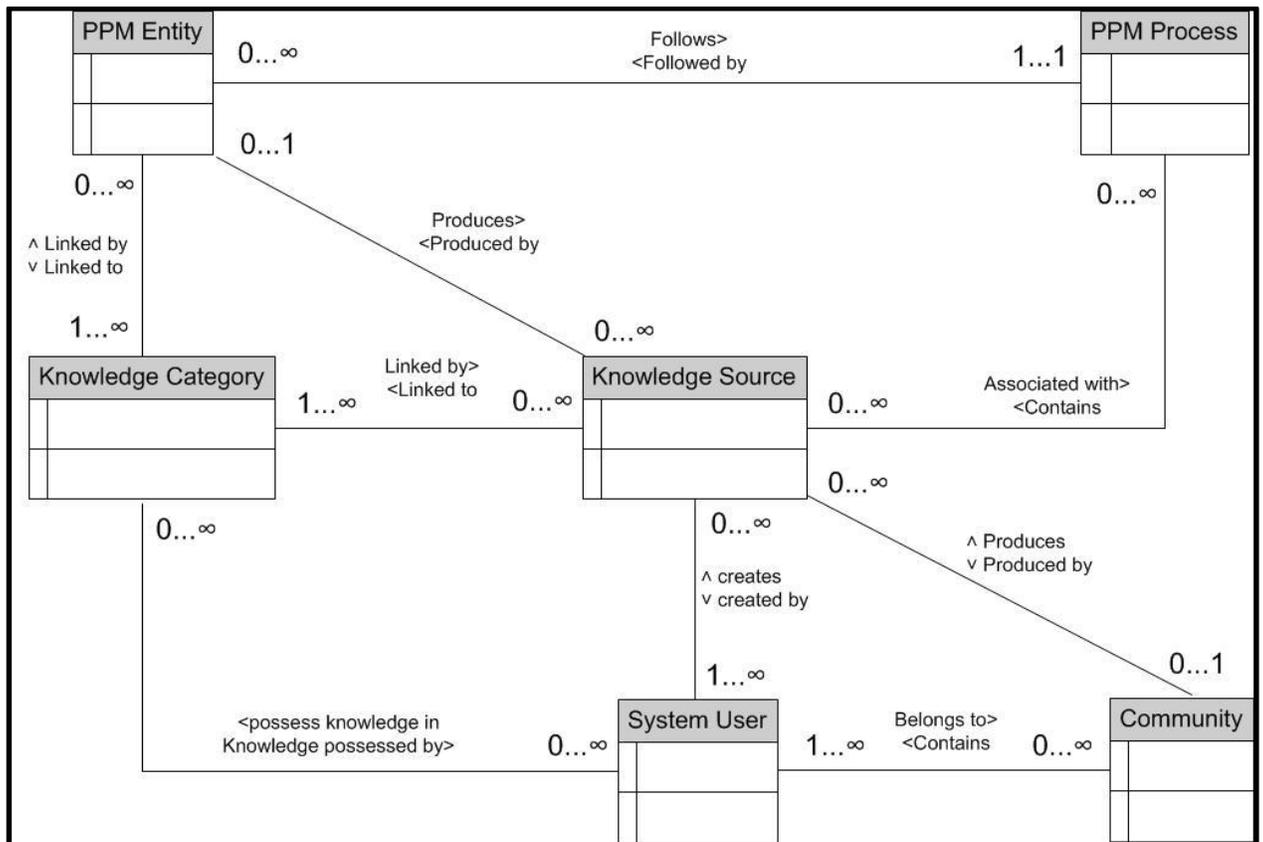


Table 12. Description of Entities in Entity Relationship Diagram of the KMS

Entity Name	Description
PPM Entity	A work unit that is independently managed, such as a proposal, project, or program.
PPM Process	A structured sequence of steps for fulfillment of a repeating organizational scenario, such as project proposal review.
Knowledge Source	A codified knowledge artifact such as a document or diagram.
Knowledge Category	A logical classification of PPM knowledge, such as “Financial Management”.
System User	A person who utilizes the KMS.

Community	A group of users who engage in a process of collective learning and interact regularly (Lave & Wenger, 1991).
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Table 13. *Description of Relationships in Entity Relationship Diagram of the KMS*

Related Entities	Cardinality	Example
PPM entity – PPM Process	Each PPM entity follows a single structured PPM process. Each PPM process has zero or more PPM entities that follow it.	Each project proposal goes through a single review and evaluation process.
PPM entity – Knowledge Source	Each PPM entity produces zero or more knowledge sources created through its lifecycle, and each knowledge source is produced by zero or one PPM entity.	“Lessons Learned” document produced by a specific proposal’s review team.
PPM Entity - Knowledge Category	Each PPM entity is linked to at least one knowledge category. Each knowledge category may be linked by zero or more PPM entities.	A proposal for a wiki project is linked to the knowledge category “Social Computing”.
Knowledge Source – Knowledge Category	Each knowledge source is linked to one or more knowledge categories, and each knowledge category is linked by zero or more knowledge sources.	A financial analysis knowledge sources is linked to the category “Financial Management”
System user – Knowledge	Each system user may	A certain user developed a

Source	create zero or more knowledge sources, and each knowledge source is created by one or more system users.	unique methodology for proposal evaluation and codifies it.
System User – Knowledge Category	Each system user may also possess knowledge in zero or more knowledge categories, and each knowledge category has zero or more users defined as possessing its knowledge.	A certain user who possesses solid financial understanding is defined as possessing knowledge in “Financial Management” knowledge category.
User – Community	Each user belongs to zero or more communities, and each community contains at least one user.	A certain user who routinely participates in project proposals’ evaluations, belong to several communities of practitioners who are routinely involved in the same process.
Community – Knowledge Source	Each community may produce zero or more knowledge sources, and each knowledge source is produced by zero or one communities.	A discussion thread on a certain topic held by community members is codified.
PPM Process – Knowledge Source	Each PPM process has zero or more knowledge sources associated with it. Each knowledge source is	Methodology artifacts have been created in support of the project portfolio review process.

	associated with zero or more processes.	
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V--SUMMARY, CONCLUSIONS, AND FUTURE DIRECTIONS

Summary and Conclusions

This research produced a high-level design of a KMS for PPM, based on an independent study which was reviewed and refined through input from field practitioners. This design work resulted in identification of twelve system capabilities, fourteen design considerations, five technologies, an ERD of the proposed solution, and a list of general system attributes. The respondents' credentials in the field, face validity, internal consistency reliability, and responses' variation were all at levels supporting the proposed design, as well as other aims of this study.

The overarching system design methodology employed in this study of independently developing a solution design based on a literature review and field experience, and only then asking field practitioners to comment on it as basis for refinements has proven itself. The respondents of the questionnaire were able to grasp the questions, connect them to their bodies of knowledge, and provided useful feedback on the proposed design. On the other hand, when field practitioners who did not participate in this study were informally asked about potential capabilities of a KMS for PPM, they provided partial and unfocused answers.

The decision to focus on a fairly high-level design for this research appeared to be appropriate for three primary reasons. First, the non-existence of similar solutions in the field mandated initiation of the process with abstract and conceptual thinking, as a logical entry point. For example, without having an appropriate definition of the term "knowledge" - a fundamental question in KMS - it would have been challenging to create an effective low-level design of specific KMS capabilities. Second, a focus on detailed design would have likely to steer the discussions toward contemporary technologies or specific organizational scenarios, and therefore defeat the intent of proposing a long-lasting, foundational design. Third, the breadth of the concept, which has been revealed

and expanded throughout this research, did not allow focus on low-level system design while maintaining a reasonable of scope of work.

This study's results are encouraging indicators of the potential value and practicality of the KMS for PPM concept as design within for a number of reasons.

First, the overall grand mean value score of 3.7/5 assigned to the proposed capabilities is a positive general indicator of the perceived importance of the identified gap and the usefulness of such a tool. Second, the three PPM processes which the KMS capabilities purport to strengthen were not challenged by a single respondent, providing future studies with a high degree of confidence with respect to the right areas of PPM to address with the KMS. Third, the fact that the proposed capabilities can be delivered through prevalent KMS technologies, which have been successfully utilized in other domains, further supports the practicality of the KMS for PPM concept, beyond just an abstract concept that "makes sense".

Simply put, this study indicates that PPM is a strong candidate for incorporation of KM and KMS, similar to other organizational disciplines, which may advance the organizational competencies in this relatively young discipline. At the same time, while all the proposed capabilities were deemed as at least "valuable", significant variance of the perceived value was found among them, which should influence the priority and resource allocation associated with further work on each one. In addition, since the overall grand mean value score is high, but not extremely high, it can be viewed as an indicator that KM, while proven important for PPM, is only one contributing factors to the general disparity between potential and actual value generation from this discipline.

The primary learning theory supporting the proposed design appeared to be a solid. From a contextual learning perspective, the questionnaire's results are not surprising in light of the fact that PPM processes share many common characteristics with other organizational processes for which these capabilities were found useful. However, the relevance of the COP concept to the KMS was more questionable, since PPM implementations typically contain mixed circumstances for their formation.

Nevertheless, the participants have demonstrated good degree of belief in the value of COPs for the PPM work (3.53/5 grand mean rating).

While these results are generally positive, it is important to keep in mind that this study only represents the first step towards the ultimate goal of enabling organizational learning in the discipline of PPM through a KM. There are certainly numerous challenges that may arise along the way, as the design is taken to a more concrete level, technology changes, and the PPM/KM domains change as well. Furthermore, a successful KMS integration goes well above and beyond an effective system design - the focus of this research - as it entails various organizational, cultural, and managerial factors. For example, some respondents, have volunteered to share some of their non-technological concerns, such as the tendency of people in organizations not to share knowledge they possess, although not specifically asked to provide non-technical feedback

To summarize, within its known limitations and intentionally limited scope in the context of the ultimate objective, this study has proven the value of the missing link in PPM environments, and characterized it in a way that was largely validated and refined by field practitioners. These results should provide researchers seeking to advance this concept with a solid starting point in terms of recommended areas of focus, considerations, and understanding of this concept's magnitude.. The next section includes more specific recommendations and guidelines for these researchers.

Future Directions

The overall positive feedback on the concept of KMS for PPM calls for continued studies in this area, and this section contain guidelines and recommendations for this future work. Since the concept of KMS for PPM has clear practical goals, these studies should continue to be performed while maintaining an effective feedback loop from the industry or otherwise run the risk of inapplicably. Another general guideline is to expand the scope of these studies well beyond technical design, as the KMS literature repeatedly

notes that successful KMS implementations entail broad organizational, managerial, and cultural factors.

From a technology perspective, the high-level design developed in this research needs to be taken to the next level by making it more concrete and detailed. This process needs to be informed by the ranking of the proposed capabilities described in this study, as it should affect the priority and allocation of resources for each one. Each of the identified capabilities needs to decompose into sub-capabilities, attributes, and behavior patterns up to the point where users are able to fully understand its operation and system architects are able to analyze the resultant technical requirements. While performing this work, it is important to keep in mind the two design considerations that dominated this study's results – knowledge quality, and system usability.

This continued design process of the KMS needs to be assisted by well-established systems analysis methods that enable a more concrete representation of its operation. For example, the ERD proposed in this study is a conceptual model and needs to be used as basis for development of more concrete models, such as data structure diagrams, which focus on the relationships of the elements *within* entities. Other tools for concrete analysis include data flow diagrams, which represent the flow of data within and information system; data models that represent physical data table structures; and the use of Unified Modeling Language (UML) diagrams, a highly prevalent general-purpose modeling language for systems analysis.

Another important factor to consider are changes to the associated knowledge domains that informed this study and certainly capable of changing the thinking behind the KMS for PPM. For example, PPM as a relatively young and dynamic field goes through important changes which researchers need to be aware of and analyze their impact on the KMS. KM and OL are better established disciplines than PPM, yet subject to new theories, trends, and discoveries that need to be monitored as well. Finally, technology itself as perhaps the most dynamic of all these areas needs to be monitored for new technologies that may enable the desired OL in more effective ways than the tools described in this study.

None of the PPM studies covered in this study provided PPM implementation recommendations, or identified specific PPM implementation patterns for different industries, geographies, or types of organizations. Similarly, leading industry PPM methodologies, such as the PMI's "Standard for Portfolio Management", specifically state that they "represent generally recognized good practices in the discipline of portfolio management" (p. 11) without specifically applying to any specific type of organizations. Along the same lines, although it would be interesting to repeat this research in pursuit of clear differences across these factors, it should be given a lower priority.

At the same time, PPM implementations vary based on factors covered in the design considerations section, such as PPM maturity level, reach of the solution, and varying roles and responsibilities. As these factors will also influence the implementation of KMS in different organizations, valuable future research should focus on KMS implementation recommendations for organizations of varying attributes across these factors. Such research, for instance, should aim to devise a set of recommendations for organizations of certain PPM maturity levels on implementation strategies of the KMS capabilities described in this study that are appropriate to their situation. The literature and the industry contain a large number of "PPM Maturity Models" that help organizations assess their PPM maturity levels and create PPM "implementation roadmaps" (Jeffery & Leliveld, 2004). Similarly, one of the objectives of future research should be to focus on expanding these models to support KM as well.

Finally, another recommended future research direction involves focus on KMS in non-IT PPM environments. Although the PPM discipline is fairly synonymous with IT projects, there is a growing penetration of PPM methods into non-IT organizational domains such as new product development, or professional services organizations (Gartner, 2010). While employing PPM methods in these disciplines serve the same overarching objectives of PPM for IT - selecting the right projects and successfully overseeing their execution - they do incorporate certain differences from IT PPM (Gartner, 2010). On the same token, it is hypothesized that only certain elements of the KMS for PPM would be relevant for non-IT PPM, a question that needs to be further researched.

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