1-1-2016

Knowledge Reuse Through Electronic Knowledge Repositories: An Empirical Study And Ontological Improvement Effort For The Manufacturing Industry

Peter Panha Chhim
Wayne State University,

KNOWLEDGE REUSE THROUGH ELECTRONIC KNOWLEDGE REPOSITORIES: AN EMPIRICAL STUDY AND ONTOLOGICAL IMPROVEMENT EFFORT FOR THE MANUFACTURING INDUSTRY

by

PETER PANHA CHHIM

DISSERTATION

Submitted to the Graduate School

of Wayne State University,

Detroit, Michigan

in partial fulfillment of the requirements

for the degree of

DOCTOR OF PHILOSOPHY

2015

MAJOR: INDUSTRIAL ENGINEERING

Approved by:

____

Advisor Date

____

Co-Advisor Date

____

____

____

DEDICATION

To My Wife, Lisa Chhim and Children, Tramy, Mimi, and Anthony

Thank you for all your support and encouragement. You are all the reason I will ever need to be a better Father and Husband.

To My Parents, John and Sorth Chhim

Thank you for instilling in me the endless pursuit of education

ACKNOWLEDGEMENTS

I would like to take this opportunity to express my deepest gratitude and appreciation to the many people who helped me during my doctoral pursuit. When I look back, I am struck by how quickly the time has passed and how much has changed since I joined the 2nd cohort of Wayne State University's Global Executive Track (GET) program in Industrial and Systems Engineering, back in the winter semester of 2009. What is most apparent to me is the birth and growth of my son, who was still in womb when I joined the program, but now is a rambunctious 6 year old who is now entering his formal education while I am exiting mine. As I take my final steps through this educational process, I reflect and express my gratitude to all those who have helped me along the way.

First, I would like to send my heartfelt and sincere thanks and appreciation to my dissertation chair, Dr. Ratna Babu Chinnam. His constant support, guidance and encouragement always reinvigorated me after each of our sessions, and I am thankful to the selfless nature in which he gave his time. Additionally, I would also like to thank him for steering me towards this multi-paper dissertation format. The learning I have acquired on how to prepare and present a journal article is invaluable and will help prepare me for post-doctoral publication.

Next, I would like to thank the rest of my dissertation committee. To Dr. Toni Somers for the endless amount of time she spent helping to improve the quantitative research portion of this dissertation, and the corresponding paper she co-published with me. Her support was constant and far exceeded the duties of a committee member. I would also like to thank Dr. Kyoung-Yun Kim for his input on the ontological portion of the dissertation, and to Dr. Leslie Monplaisir for his help and guidance throughout. I would also like to thank Dr. Noureddin Sadawi for his pragmatic and insightful videos on Protégé and the semantic web. His knowledge sharing helped me to gain a familiarity in this area necessary to complete the ontological portion of the research. Finally, and sadly, one of my original committee members was unable to make it to this final stage, as Dr. Frank Plonka passed away October 29th 2014. Although physically unable to join me now, I know he is watching and I want to be certain to thank him for helping to guide me through the APQP and FMEA processes, and providing valuable insight into the knowledge reuse possible through them. Thank you Dr. Plonka, and may you rest in peace.

Finally, I want to thank my family. First, I want to thank my loving wife, Lisa Be Chhim, and my girls Tramy and Mimi for their constant encouragement, support and understanding as I worked to balance the requirements of work, home and school life. You have been with me every step of the way through this journey, and your resolve and inspiration never waned, thank you for always believing in me. Next, I want to thank my parents John and Sorth Chhim, for instilling in me the lifelong pursuit of education and the belief that I could achieve whatever I set my mind to. Lastly, I want to thank all my direct and extended family members for their patience and encouragement throughout this process. I cannot express enough how much motivation and inspiration you have provided me through this effort, thank you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

In an increasingly globalized world where competition advances at a fierce pace, the strategic management of knowledge continues to be a significant topic for organizations. Knowledge has been defined as a justified belief that increases an entity's capacity for effective action (Huber, 1991; Nonaka, 1994), or succinctly put, knowledge is actionable information (Maglitta, 1996). This actionable information is not limited to the improvement of an organization's products, but also to its business and operational processes as well. Hence, knowledge is a differentiator that can enhance an organization's value proposition. This position is shared in the academic community where knowledge has been identified as both a key competitive advantage as well as a source for economic prosperity (Dierickx & Cook, 1989; Nonaka, 1994; Lei, Hitt, & Bettis, 1996; Alavi & Leidner, 2001). Consequently, organizations continue to invest in Knowledge Management (KM). In a published report by AMR research, U.S. spending on KM initiatives totaled $73 billion dollars in 2007 (Mcgreevy, The Knowledge Management Spending Report , 2007), a figure that has likely risen and will continue to rise in no small part from the inclusion of KM as a key addition to the upcoming industrial quality management standard, ISO 9001: 2015 (Palmes, 2014). An area where these initiatives are being applied is Information Technology (IT), and in particular the use of IT to develop Knowledge Management Systems (KMS).

Knowledge Management Systems are defined as a class of information systems designed specifically to manage an organization's knowledge (Alavi & Leidner, 1999). Distinctly, they are IT based systems intended to support and enhance an organization's ability to create, store, retrieve, transfer and apply knowledge (Alavi & Leidner, 2001). An increasingly popular form of KMS is Electronic Knowledge Repositories (EKR). An EKR is defined as an electronic storage location where organizations have decided to maintain knowledge (Liebowitz & Beckman, 1998). These repositories are useful sources for KM in that they both retain and provide access to organizational knowledge. Additionally, access to this codified expertise also makes EKRs quite useful for the purpose of knowledge reuse. For example, a user could access and reuse this knowledge to mitigate potential problems and obtain greater business efficiency by not having to reinvent solutions (Akgun, Byrne, Keskin, Lynn, & Imamoglu, 2005). As organizations recognize and attempt to reap these benefits, the codified approach to KM continues to gain momentum. As Saito, Umemoto, & Ikeda (2007) indicate, the technology oriented approach to KM seems to be the most common. Some examples of this approach include an offering from Ernst and Young, a multi-national professional services firm that developed a sophisticated knowledge web that holds some 350,000 knowledge items for its consultants to query (Dixon, 2000). Another example is from Ford Motor Company, who championed an EKR that that has grown to over 600 items and involves thirty-seven plants around the world (Dixon, 2000). As well, NASA recently launched a 'one-click and one-stop shop' for finding Lessons Learned to ensure that website visitors, both from NASA and the public, could easily access lessons learned (NASA, 2015). Unfortunately though, just developing these systems is not enough to ensure their success. Consequently, although the benefits of EKRs are well known, the research surrounding them is sparse. In particular, numerous researchers have pointed out that the factors affecting Knowledge Reuse (KRU) through EKRs is not well understood (Markus, 2001; Kankanhalli et al., 2005b; Boh, 2008; He & Wei, 2009).

Fortunately though, there have been a handful of studies aimed at better understanding EKRs and the factors surrounding their usage. The studies have focused on knowledge contribution and reuse (Watson & Hewett, 2006), facilitation of reuse through the knowledge provider (Boh, 2008), continuance of use (He & Wei, 2009), benefits and motivations for EKR usage (Kankanhall et al., 2005a; Kankanhalli, et al., 2005b) and KRU itself (Kankanhalli et al., 2011). Unfortunately though, only a few studies actually touch upon the subject of KRU, and even in these cases the perspective is narrow. Additionally, although knowledge management within the manufacturing industry is expected to significantly increase due to its recent inclusion in the ISO 9001: 2015 standard (Palmes, 2014), the industry is empirically underrepresented within the EKR literature, and hence requires additional effort to provide both theoretical and industrial insight at this critical juncture in time. Consequently, to increase our understanding of KRU and support the need for more representation and contribution to the industry, the research will conduct a broader systemic assessment of KRU while targeting the manufacturing industry as its contextual base. Furthermore, to operationalize the research effort, a conceptual model will be developed encompassing KRU from a multi theoretical perspective that informs both front end antecedents, as well as back end resulting outcomes. The theories informing the model are the Socio-Technical Theory and the Expectation Confirmation Model.

The Socio-Technical Theory was originally introduced by Trist and Bamforth (1951) to posit that a production system cannot be viewed solely from either a social or technical perspective, and that both are interdependently connected. Within the knowledge management community, the theory has gained attention for its ability to describe KMS. In particular, the social element of the theory refers to an organization's culture, structure, and its people, while the technical element refers to the Information Technology (IT) that enables it (Lee & Choi, 2003; Whitworth, 2006; Kankanhalli et al., 2011). Within this research effort, the theory will be used to inform front end antecedents comprised of both social and technical constructs posited to influence KRU via EKRs. Next, from a resulting outcome perspective the use of the Expectation Confirmation Model (ECM) will be employed to describe the effect KRU has on downstream organizational constructs.

ECM was developed by Bhattacherjee (2001) to explain users' intention for continued Information System (IS) usage. To do so, ECM uses three antecedents to predict continuance of use: User Satisfaction, User Confirmation, and Post Adoption Expectations. In terms of IS usage, continuance of use is of critical importance for system sustainability. In the case of EKRs, the importance is magnified given the utility of the system is tied to continual knowledge seeking and contribution practices from the users. Hence, the resulting model centers KRU via EKRs between front end antecedents informed via the Socio-Technical Theory, and back end resulting outcomes informed by the ECM. This framework provides a broader assessment of KRU that will help close the research gap and contribute to both theory and practice. Next, while increasing our understanding of KRU via EKRs contributes to the existing body of the knowledge, an equally important contribution can also be made to the functional advancement of EKRs as well. As Choi et al. (2010) indicate, the use of IT has played a positive role on both knowledge sharing and knowledge application.

An area where EKR enhancement can be particularly beneficial is the design and manufacturing industry. In this industry, several barriers to greater knowledge sharing have been identified, i.e., growing information complexity (Lin et al., 2011), inconsistent terminology (Lin & Harding, 2007; Lin et al., 2011), insufficient information retrieval tools (Iyer, Jayanit, Lou, Kalyanaraman, & Ramani, 2005; Li, Yang, & Ramni, 2009), and a lack of widely accessible knowledge repositories (Chandrasegaran, et al., 2013). This lack of knowledge sharing contributes directly to a decrease in knowledge reuse as the latter has been defined as the 'sharing of best practices' (Markus, 2001). Fortunately, ontologies have been identified as a tool that can address these issues, largely in part for their ability to share information within a particular domain (Swartout et al., 1996; Studer et al., 1998; Noy & McGuinness, 2001; Lin & Harding, 2007).

An ontology is defined (Borst, 1997) as an, 'explicit formal specification of a shared conceptualization.' To provide further clarity, Studer et al. (1998) dissect the anatomy of this definition and explain that the term 'formal' refers to the necessity of the ontology to be machine readable, while 'explicit specification' indicates that the concepts need to be explicitly defined, and 'shared conceptualization' requires that the ontology represents consensual knowledge of real world phenomena. Interest in ontologies has grown in recent years, and as result they've moved beyond the realm of computer science and onto the desktop of domain experts (Noy & McGuinness, 2001). This increase in popularity can be derived in large part due to their ability to share information within a particular domain (Swartout, Patil, Knight, & Russ, 1996; Studer, Benjamins, & Fensel, 1998; Noy & McGuinness, 2001; Lin & Harding, 2007). Prior to the development of ontologies, knowledge bases were difficult to share or reuse, even when expressed in the same formalism and covering the same domain (Swartout, Patil, Knight, & Russ, 1996). Swartout et al., (1996) support this view by contending that the problem stems from a lack of a shared terminology and structure for the knowledge bases. This issue is magnified from an organizational standpoint as knowledge is often distributed not only functionally, but also geographically. As Desouza & Evaristo (2003) indicate, knowledge is often spread over a wide spectrum and is meshed in a broad context. This makes the challenge of managing knowledge, and in particular gaining from knowledge reuse quite difficult. Furthermore, these challenges are amplified between organizations as the growing complexity of information, specifically the knowledge and information required by a wide range of users has made it increasingly difficult to share and exchange (Lin & Harding, 2007). Fortunately, by utilizing ontologies, isolated, fragmented and unrelated knowledge can be transformed into interrelated, systematic and structured knowledge; ultimately making it useable and searchable (Zhao and Zhu, 2012). As

Niles & Pease (2001) indicate, this avoids having to re-invent the wheel with better integration and maintenance of existing knowledge. Consequently, an expected ancillary benefit of greater knowledge sharing is a positive resultant effect on greater knowledge reuse. With the advent of the semantic web and its ontology friendly architecture, the potential for improved knowledge structuring, knowledge sharing and knowledge reuse has significantly increased.

Hence, this research has two primary objectives pertaining to knowledge reuse through EKRs. First, to help close the gap pertaining to a lack of understanding surrounding the factors affecting KRU via EKRs, the research will conduct a broad examination of KRU through front end antecedents, as well as back end resulting outcomes. In particular, the research examines: (1) How does the application of a front end Sociotechnical framework impact KRU via EKRs? (2) Within the context of ECM, what resulting effect does KRU via EKRs have on performance, knowledge sharing and continuance of use? (3) How does the interplay of antecedents and resulting outcomes affect KRU via EKRs? The use of these theoretical perspectives will help to identify pertinent research variables, their placement in the model and their associated hypotheses. The testing of these hypotheses will come by way of survey data which will be collected primarily from the manufacturing industry, but will also include other industries to help improve the generalizability of the results. Additionally, the pool of respondents will be limited to those with EKR experience so that pertinent inputs can obtained test the research model's various hypotheses. The results from this objective will contribute to both research and practice. From the research perspective, the effort will help to shed further light on the factors surrounding KRU through EKRs, and provide a first view of this area from a comprehensive front and back end perspective. From a practical standpoint, the findings from the study will be used to inform industry practitioners on the enhancement of KRU through EKRs.

The second objective of this research pertains to the enhancement of EKRs via Semantic Web technology, and in particular ontologies. To inform the development effort, the research will key in on the manufacturing industry and will borrow from one of its mature industry processes that interconnects key concepts from both the process and design domains. In taking this approach, the research will build upon existing ontological efforts that have either focused broadly on manufacturing enterprise based efforts (Lin et al., 2004; Lin & Harding, 2007; Lin et al., 2011), or narrowly on design (Kitamura & Mizoguchi, 2004; Kim et al., 2006; Chang et al., 2010) and failure mode based efforts (Lee B. H., 2001; Dittmann, Rademacher, & Zelewski, 2004; Laaroussi, Fies, Vankeisbelckt, & Hans, 2007; Ebrahimimpour, Rezaie, & Shokravi, 2010; Molhanec, Zhuravskaya, Povolotskaya, & Tarba, 2011; Xiuxu & Yuming, 2012). In contrast, the resulting ontology will help to bridge the knowledge sharing gap by offering a more complete, and industry related effort that interconnects design and process knowledge. Furthermore, to address a concern regarding the lack of wide spread ontology usage (Lin, Zhang, Lou, Chu, & Cai, 2011), the research will also offer a systematic and constructive methodology for ontology development. A look at the combination of these two research efforts and their impact on KRU via EKRs can be seen in Figure 1 below.

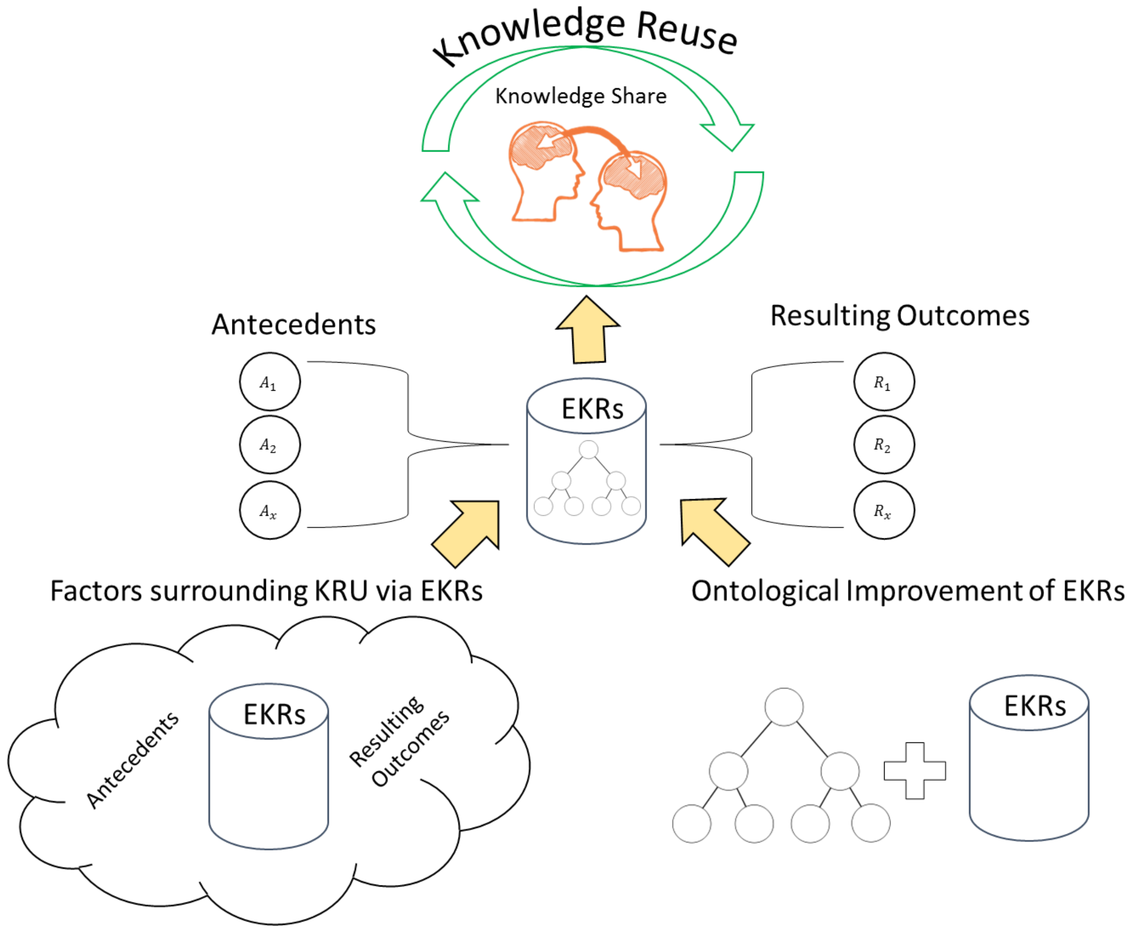


Figure 1: Dissertation research efforts and their connection to KRU via EKRs

Finally, and in the spirit of the Global Executive Track (GET) program in Industrial and Systems Engineering in which this dissertation is presented, the research is capped off with the presentation of broader, knowledge management recommendations for organizational leadership. As mentioned earlier, knowledge management is becoming more prevalent in industry and with its inclusion into the ISO 9001 quality standard, an overwhelming number of organizations will be tasked with implementing it to satisfy compliance. Given the GET program was designed for working level professionals with the aim of developing a new class of technical industry leaders (Wayne State University, 2015), as my journey through this program winds down, there's an inherent obligation to provide pertinent industry recommendations to both inform organizational leadership, and also demonstrate the capability of the program. Consequently, pragmatic and actionable suggestions drawn upon popular press and industry specific literature will be used in junction with findings from this research to better inform organizational leadership.

The remainder of this dissertation is organized as follows: Chapter two describes the results from the empirical study pertaining to KRU via EKRs. Chapter three describes the design and process based ontology for enhancing manufacturing EKRs. Lastly, Chapter four concludes the research with a summary of the findings, limitations and direction on future research, as well as the aforementioned managerial suggestions to provide a holistic and program specific framing of the KM discussion.

CHAPTER 2: KNOWLEDGE REUSE THROUGH ELECTRONIC KNOWLEDGE REPOSITORIES: AN EMPIRICAL STUDY OF ORGANIZATIONAL ANTECEDENTS AND RESULTING OUTCOMES

Introduction

In an increasingly globalized world where competition advances at a fierce pace, the strategic management of knowledge continues to be a significant topic for organizations. In a recent survey conducted by the Technology Services Industry Association, nearly 60% of respondents from the support, professional and education fields indicated that they planned to invest in Knowledge Management (KM) (Coveo and TSIA, 2014). Additionally, this adoption rate will positively increase due to KM's inclusion in the upcoming, and ubiquitous quality management standard, ISO 9001: 2015 (Palmes, 2014). An inclusion that can't be overlooked, given that as of 2013 over 1.1 million companies worldwide were certified to the ISO 9001 standard (ISO, 2014)! Consequently, companies continue to invest in the collection, codification and storage of organizational knowledge. A manifestation of these efforts often appears as an Electronic Knowledge Repository, or EKR.

An EKR is defined as an electronic storage location where organizations have decided to maintain knowledge (Liebowitz & Beckman, 1998). These repositories are useful sources for Knowledge Reuse (KRU) in that they can provide codified expertise at times of need, and help mitigate potential problems while providing greater business efficiency in not having to reinvent solutions (Akgun et al., 2005). Unfortunately, while tens of billions are spent on Knowledge Management (KM) software (Mcgreevy, The Knowledge Management Spending Report, 2007), well documented examples of successful KM projects remain elusive (Kimble, 2013). A key concern impacting this issue is that the factors affecting KRU through EKRs is not well understood (Markus, 2001; Boh, 2008; Kankanhalli et al., 2011). Additionally, there has been sparse research that has examined the resulting impact of KRU via EKRs, and none to our knowledge that have attempted to broadly model KRU via EKRs by including both front end antecedents and back end resulting outcomes.

Studies of EKRs have generally taken one of two perspectives: knowledge contribution (Kankanhalli et al., 2005a; Watson & Hewett, 2006) or knowledge seeking (Kankanhalli et al., 2005b; Bock et al., 2010). These two perspectives are logically sound approaches in that they essentially reflect the fundamental usage of EKRs. Additionally, numerous recent studies continue to till the EKR land (Boh, 2008; He & Wei, 2009; Tha & Khet, 2010, Kankanhalli et al., 2011; Lin & Fan, 2012; Aggestam, Durst, & Persson, 2014; Choi & Durcikova, 2014; Fadel & Durcikova, 2014), further emphasizing the importance and relevance of this domain as the research stream continues along the same industry path of greater KM emphasis and EKR usage. However, while these efforts undoubtedly help to expand our understanding of EKR usage, there has yet to be a systemic broader evaluation of KRU that can further enhance theory and practice. In particular, by connecting KRU through a front end piece i.e. those factors that facilitate KRU, informed by the Socio-technical theory, and a back end piece i.e. factors affected by KRU, constructed via the Expectation Confirmation Model (ECM) perspective, we feel we can provide this broader evaluation while closing this research gap and contributing to the literature. Hence, our research asks the questions: (1) How does the application of a front end Socio-technical framework impact KRU via EKRs? (2) Within the context of ECM, what resulting effect does KRU via EKRs have on performance, knowledge sharing and continuance of use? (3) How does the interplay of antecedents and resulting outcomes affect KRU via EKRs? We believe the answers to these questions will help to further our understanding of EKRs and key in one its primary motivators, i.e., knowledge reuse. A conceptual view of our model is provided in Figure 2.

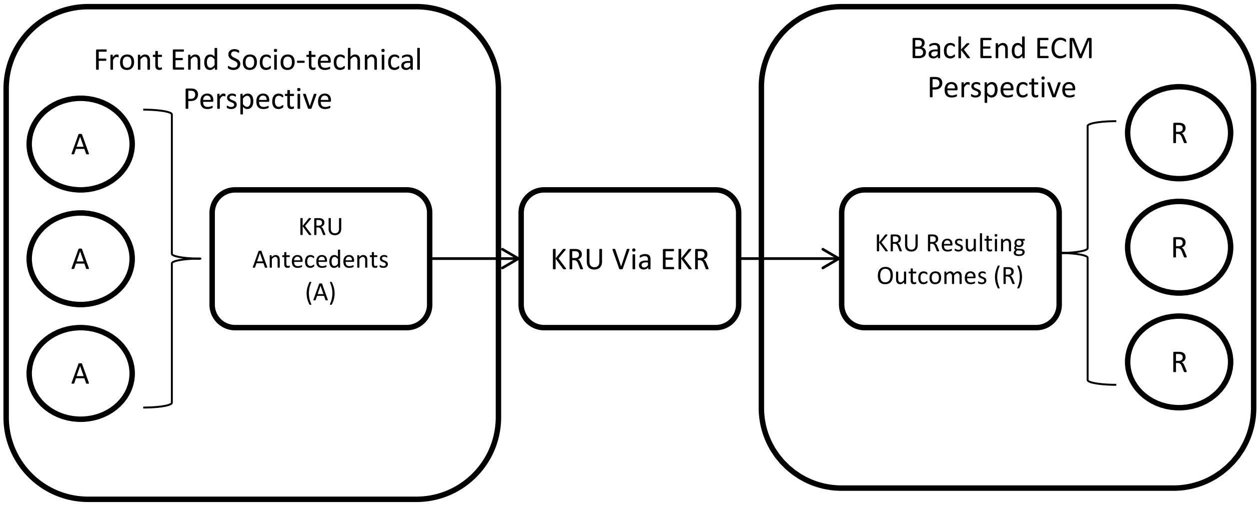


Figure 2: Conceptual Model of KRU via Antecedent and Resulting Outcome Perspective

Theoretical Background

Prior studies on EKRs have utilized theories from the Information Systems (IS) and social science fields. In particular, Technology Acceptance Models (TAM), social exchange and capital theory, knowledge transfer models (Kankanhalli et al., 2011) and IS continuance literature has been used to ground research efforts. In the case of TAM and IS continuance research, it is logically sound to employ both views either independently or jointly, as EKRs are ultimately a form of IS and hence their initial acceptance as well as ongoing continuance of use are vital for long term success. Bhattacherjee (2001) developed and empirically validated the Expectation - Confirmation Model (ECM) to explain users' intention for continued Information System (IS) usage. ECM uses three antecedents to predict continuance of use: User Satisfaction, User Confirmation, and Post Adoption Expectations. The model posits that a user's confirmation and perceived usefulness influence satisfaction which in turn influence the user's intention to continue using the IS. Given our study is intended to provide a broader view of KRU via EKRs, we use the ECM to inform and frame our model via front end antecedents, as well as resulting outcome factors. From the front end piece, we are interested in identifying those factors that will facilitate

KRU via user satisfaction and confirmation, while on the back end we look to connect factors that would suggest greater continuance of use. The back end factors are of particular importance as continued seeking and contributing routines are essential to ensuring EKRs remain relevant, and in use. While these theories are useful in explaining initial and ongoing usage behaviors, they do not account for the factors associated to knowledge seeking and contributing activities. To do so, researchers have applied social exchange, social capital theory and knowledge transfer frameworks.

Social exchange theory attempts to explain the nature of social exchanges between parties, and posits that people contribute or exchange with others commensurate to what they perceive others are providing to them (Blau, 1964). Consequently, knowledge-sharing can be viewed as a generalized form of social exchange (Fulk et al., 1996), as users exhibit this behavior in the form of knowledge seeking and knowledge contributing activities (Kankanhalli et al., 2005a). However, while social exchange theory informs cost and benefit factors associated to knowledge exchange, it doesn't account for the contextual and broader organizational factors that help shape the social and technological factors that help interconnect the human relationships within the knowledge network. To account for these factors, our study uses Social-technical Systems theory to inform larger, organizational level factors that have yet to be modeled within the context of KRU via EKRs research.

The Socio-technical Systems Theory posits that a production system cannot be seen independently as either a technical or social system, and that both co-exist interdependently as a socio-technical system (Trist and Bamforth, 1951). Within the context of knowledge management, the social element of the theory utilizes an organization's culture, structure, and its people as its enablers, while information technology (IT) is employed as the technical enabler (Lee & Choi, 2003; Whitworth, 2006; Kankanhalli et al., 2011). This position is validated by the fact that EKRs are built upon on a technical core of IT; however in order for them to function they require both cognitive and social interaction from the system users, i.e., people. Consequently, the use of the theory has gained popularity as researchers leverage the connection between human practices and technology (Kankanhalli et al., 2011). Given these perspectives are made up of jointly independent but correlative interacting components (Lee & Choi, 2003), for the sake of clarity we choose to identify and discuss the variables separately. Finally, we feel that the use of this perspective in framing our front end antecedents is wholly appropriate and provides a logically sound lead-in to our back end ECM factors.

Hypotheses and Research Model

Our research model integrates a dual theoretical approach comprised of the ECM and Social-technical Systems theory to provide a relevant and broader view of KRU via EKRs. Below we discuss the factors associated to each theory and their respective hypotheses. We begin with a review of the Socio-technical factors comprising our model.

Socio-technical Factors

Employing a similar approach as Lee and Choi (2003), we identify socio and technical factors independently, however within our model we jointly connect them. Additionally, our factors are representative of well-known knowledge management enablers. Table 1 below shows the factors comprising these respective portions of the Socio-technical theory within our model.

Table 1: Knowledge Management Enablers Via Socio and Technical Factors

Socio – Technical Theory Factors		**KM Enablers**
Socio - Factors	Learning Culture	***Organizational Culture*** (Hedlund, 1994; Gold, Malhotra, & Segars, 2001)
	Worker Interaction and Collaboration	***People*** (Chase, 1997; Holsapple & Joshi, 2001)
	Knowledge Management Strategy	***Organizational Structure*** (Hansen, M.T.; Nohria, N.; Tierney, T., 1999)
Technical Factors	End User Computing Satisfaction	***Information Technology*** (Gold & Arvind Malhotra, 2001)
	Knowledge Validation Process	
	IT Support	

Socio-technical: Socio Factors

Learning Culture

Learning culture is defined as the degree to which organizations encourage learning through means such as education, training, and mentoring (Hurley & Hult, 1998). Numerous scholars have long acknowledged the importance of a learning orientation to overall firm performance (Slater & Narver, 1994; Calantone et al., 2002) and consequently the presence of supportive values and beliefs that encourage employee inquisitiveness, creativity, willingness to learn from error, and openness to sharing knowledge are viewed as significant contributors to an organization's learning culture (Lee-Kelley, Blackman, & Hurst, 2007). Additionally, studies have shown that a learning culture has a positive influence on both knowledge process capabilities (Lee, Kim, & Kim, 2012) and knowledge creation processes (Lee & Choi, 2003). Thus, within the context of KRU through EKRs, and broad swath that culture can cast across an organization, we expect Learning Culture to play several roles. Hence, we posit that:

H5a – Learning Culture positively influences KRU through EKRs

H5b – Learning Culture partially mediates the influence of WIC on KRU through EKRs

H5c– Learning Culture partially mediates the influence of KMST on KRU through EKRs

Worker Interaction and Collaboration

For centuries, knowledge has been passed down from generation to generation through family businesses and mentor to apprentice connections (Hansen, et al., 1999). This personal method of knowledge transfer acknowledges the tacit dimension of knowledge and its ability to be shared primarily through direct interpersonal communication (Hanh & Subramani, 2000). As Droege and Hoobler (2003) indicate, 'When the right people come together, the odds of diffusing tacit knowledge to others are increased'. Consequently, modern industrial organizations can effectively extend their potential to create knowledge by focusing on interaction with others (Perez-Bustamante, 1999). In a study by Tsai, Chen, and Chin (2010), collaboration was identified as a significant contributor to a knowledge worker’s innovation performance. Additionally, Kang (2013) found that without question collaboration is grounded in human interaction and relationships. Given collaboration's impact on knowledge creation, we propose that this tacit benefit is also expansive and impacts KRU. Consequently, we propose that:

H3 – Worker Interaction and Collaboration (WIC) positively influences KRU through Electronic Knowledge Repositories (EKRs)

Knowledge Management Strategy

Knowledge strategy is ‘the overall approach an organization intends to take to align its knowledge resources and capabilities to the intellectual requirements of its strategy (Zack, 1999). As Hansen et al. (1999) imply, this intellectual alignment extends to an organization's economic model and includes how it utilizes its people to accomplish this feat. Two commonly applied approaches to knowledge management are the system-oriented or codification approach, and the human-oriented or personalization approach (Hansen et al., 1999). In the case of EKRs, the codification approach of knowledge applies as explicit knowledge is extracted and made independent for the purpose of reuse. While the selection of a particular approach varies depending on organizational need, both have been found to impact innovation and organizational performance (Lopez-Nicolas & Merono-Cerdan, 2011). Additionally, the differences between each choice and their respective impact has been found to be negligible (Vaccaro et al., 2010; Lopez-Nicolas & Merono-Cerdan, 2011). An ancillary benefit implementation of a KM strategy is that knowledge worker retention is enhanced when employees see that top leaders exhibit understanding and support of intellectual capital through structures, process and systems (Stewart & Ruckdeschel, 1988). Hence, we posit that:

H4 – Knowledge Management Strategy (KMST) positively influences KRU through EKRs

Socio-technical: Technical Factors

Information Technology Support of Knowledge Repository

In the context of knowledge management, Information Technology Support (ITS) refers to the extent in which knowledge management is supported by IT (Gold et al., 2001). Unfortunately, its effectiveness in facilitating knowledge management remains unclear (He & Wei, 2009; Kankanhalli, et al., 2011). Fortunately, there have been some recent efforts aimed at better understanding this relationship. Particularly, researchers have found that ITS had a positive impact on knowledge sharing and knowledge application (Choi, Lee, & Yoo, 2010) as well as knowledge creation (Lee, Kim, & Kim, 2012). In the context of our study, we suspect that ITS will play a dual role in that it may have both a mediating as well as a direct effect on KRU through EKRS. Additionally, our work will help further identify the role ITS plays in facilitating knowledge management by applying it within the context of KRU. This connection is to the best of our knowledge, an area that has yet to be studied. Consequently we posit:

H2a – Information Technology Support positively influences KRU through EKRs

H2b - ITS partially mediates the influence of EUCS on KRU through EKRs

End User Computing Satisfaction

Assessing the effectiveness of organizational information systems has long been identified as one of the most critical issues of IS management (Ball & Harris, 1982). End User Computing Satisfaction (EUCS) is a twelve-item construct comprised of five factors: Content, Accuracy, Format, Ease of Use, and Timeliness, that measures a user's attitude towards a specific application (Doll & Torkzadeh, 1998). It merges characteristics of the application with a satisfaction element to provide a comprehensive view of the user's attitude towards the information system. In terms of the ease of use component, Davis (1989) explains that the application must not be too difficult to use, or require more effort than it delivers in performance because users may end up rejecting it. Additionally, the quality and content of the EKR are important in the success of KRU because as Markus points out (2001), there are different types of knowledge reusers, for example, novices, experts, data miners, who access it so the repository must be capable of adequately meeting their needs. Logically then, an increase in a user's satisfaction with an EKR affects their attitude towards continuance of use and by extension the likelihood of greater KRU. Thus we posit:

H1 – End User Computing Satisfaction (EUCS) positively influences KRU through EKRs

Knowledge Validation Process

A Knowledge Validation Process (KVP) begins when a repository contributor submits codified knowledge for inclusion into a repository, and it ends when that contribution is either accepted or rejected (Durcikova & Gray, 2009). Essentially then, a KVP is a process that provides a disposition for a repository submission. The KM literature maintains that strict validation processes will have a beneficial impact on the quality of knowledge held within a repository, and that it will increase the value of a repository to knowledge seekers (Markus, 2001; Crowley, 1997;

Zack, 1999). As Markus (2001) indicates, it is important to identify the factors that influence the quality and contents of knowledge repositories. Given the role KVP plays in the quality of a repository's knowledge inventory, we posit that it will have a dual impact within our study.

H6a – KVP positively influences KRU through EKRs

H6b – KVP partially mediates the influence of EUCS on KRU through EKRs

ECM Factors

In keeping with the spirit of ECM, we structure the back end of our model to include factors that would support a user's intention to continue using an EKR. Particularly, we surmise that as users reuse knowledge within the repository this in turn positively affects performance, which in turn leads to greater knowledge sharing and continuance of use. A closer look at the variables that comprise this perspective follows.

Knowledge Reuse

KRU is the process by which an entity is able to locate and use shared knowledge (Alavi & Leidner, 2001). This reuse is considered a major justification for Knowledge Management (Markus, 2001) in that if knowledge creation is not shared or reused within an organization, it is of limited value (Janz & Prasarnphanich, 2003). Additionally, KRU has been lauded for its ability to provide gains in productivity by reusing previously validated solutions and by providing codified knowledge in times of need (Davenport & Prusak, 1998; Akgun et al., 2005; Kankanhalli et al., 2011). Given the gains in performance via KRU, we posit:

H7: Knowledge Reuse (KRU) through EKRs positively influences worker Performance (PER)

Performance

Ultimately, KM programs are effective when performance improves. As result, it is important to measure the contribution KM programs have on performance (Tseng, 2008). Reusing knowledge is considered to be an intermediate outcome that enhances work performance (Kankanhalli et al., 2011). This outcome includes quicker and less costly activities since the re-user can effectively leverage previously validated solutions. In the context of IT, leveraging knowledge has been found to enhance performance by producing better outcomes such as knowledge contribution, product innovation and sales (Sambamurthy et al., 2003). Despite this finding, few studies have empirically tested the link between knowledge and performance (Tseng, 2008), and hence the extant literature does not provide a clear understanding of the real impact KM has on performance (Choi et al., 2008). As a result, our study aims to help address this gap by providing empirical results pertaining to the relationship between KRU and performance. Thus, we posit:

H8a – PER positively influences Continuance of use (CON) of EKRs

H8b - PER positively influences Knowledge Sharing (KS)

Knowledge Sharing

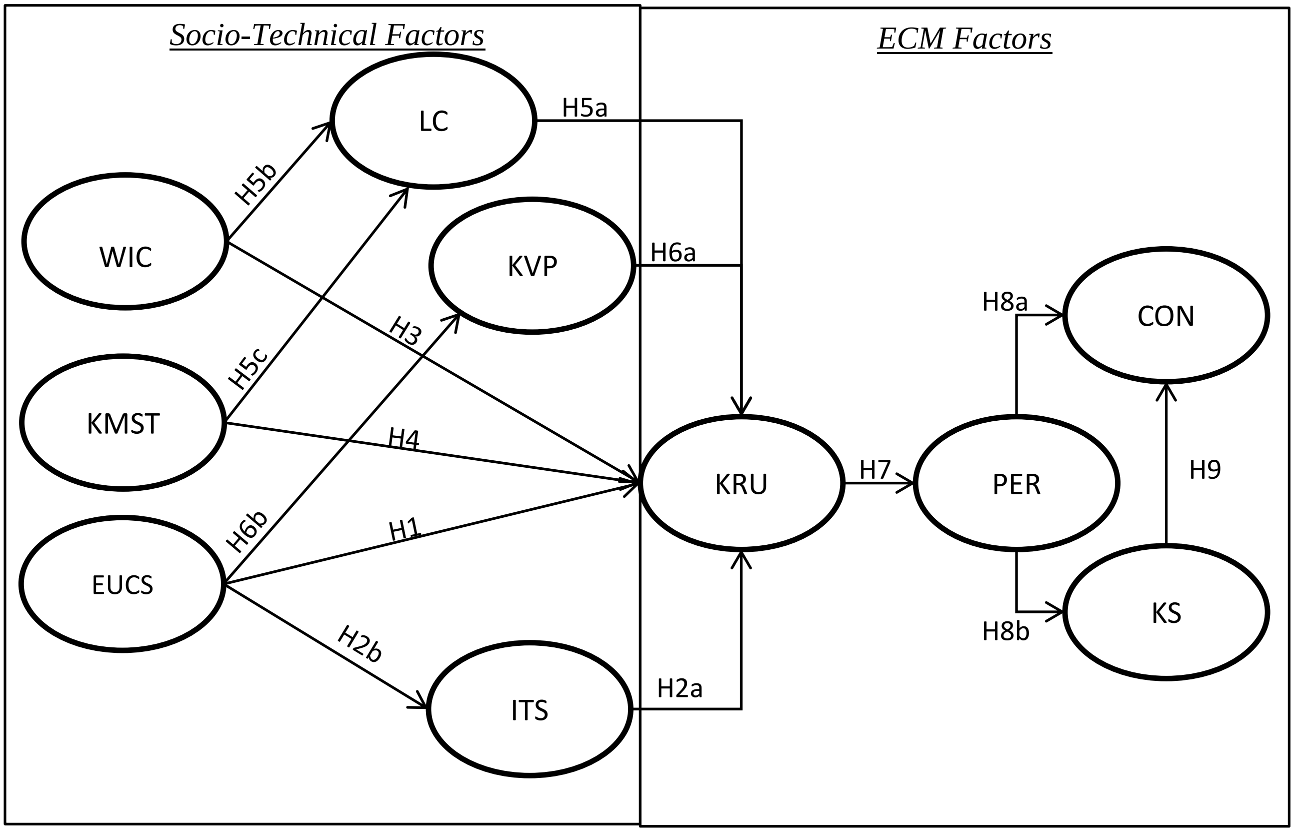
Alavi and Leidner (2001) describe knowledge sharing as the process of locating distributed organizational knowledge and transferring it to another context where it is needed. Past research has clearly been able to show knowledge sharing as a positive contributor to team performance in different contexts (Hansen, 2002; Choi et al., 2010). As Hendriks (1999) indicates, technology can enhance knowledge sharing by lowering temporal and spatial barriers between knowledge workers and by improving access to information about knowledge. We surmise then, that as users draw and reuse knowledge from the EKR their performance improves which reinforces and ultimately leads to greater knowledge sharing. Thus we hypothesize:

H9a– KS positively influences CON of EKRs

H9b – KS partially mediates the influence of PER on CON of EKRs

Continuance

Continuance is the continued use behavior of a particular IS (Bhattacherjee, 2001) relative to its first adoption (He & Wei, 2009). Given the resources and efforts required to implement a KMS, it is crucial to understand the factors that impact their continued usage. This is of particular importance given failure rates for KMS have been reported at more than 80% (Storey & Barnett, 2000). As Wasko and Faraj (2005) indicate, once IT is implemented the organization's expectations can only be met when the technologies are continually used by its employees. Within Knowledge Management, there has been surprisingly little research on continuance (Lin, 2006). In the few studies conducted, He and Wei (2009) did find that contribution and seeking perspectives, along with organizational facilitating conditions, collectively predicted continued use of an organizational EKR. Although, it must be noted though that He and Wei's (2009) findings were limited to a single company and hence the need for a broader sampling is needed. Lin and Fan (2012) found support for user commitment in the continuing use of EKRs. However, neither of these cases assess a tie in with KRU and its effect on CON. Thus, we include CON as a variable in our model to bridge this gap and identify the relational link between KRU and CON. The final research model is depicted in Figure 3 below.



WIC - Worker Interaction & Collaboration LC - Learning Culture PER - Performance
KMST - Knowledge Management Strategy KVP - Knowledge Validation Process KS - Knowledge Sharing
EUCS - End User Computing Satisfaction ITS - Information Technology Support CON -Continuance of Use

Figure 3: Research Model of Knowledge Reuse via Electronic Knowledge Repositories

Research Methodology

To test the research model and its associated hypotheses, a survey instrument was developed and the survey methodology was employed.

Operationalization of Constructs

We used validated items from prior research and adapted them to the context of EKRs. All scales are reflective. For a complete view of the constructs and their respective sources, refer to Appendix A.

Method

We conducted a survey using an electronically mediated data collection method. The utilization of electronic distribution of surveys via online and email is now widely used as it offers researchers low cost, good response rates, and quick response times (Sheehan and McMillan 1999). Prior to launching the survey, the survey was pre- and pilot-tested. First, the survey was pre-tested by five academic colleagues for clarity, readability and logical flow. As a result, several minor changes were made to improve the instrument. Next, the survey was pilot-tested by three industrial colleagues, all of which had previous experience with EKRs, and none of which participated in the pre-testing. The responses from the three did not reveal any inconsistencies or significant concerns, and subsequently the survey was launched in March of 2014.

Data Analysis and Results

Sample Demographic

Respondents for the survey were sought from knowledge intensive industries where KM efforts can be commonly found, e.g. automotive, IT, service, consulting. Consistent with prior EKR studies, respondents from the IT (Kankanhalli et al., 2005a; He & Wei, 2009) and consulting (Boh, 2008) fields represented large percentages of the sample. However, the manufacturing industry, an empirically under-represented sector in the EKR literature, was the primary target audience for our research and favorably represented nearly 40% of our respondents.

Of note, within this industry designers prefer to use concepts and lessons of past designs (Khadilkar & Stauffer, 1996), primarily because the largest accumulation of expertise is stored within them (Shahin, Andrews, & Sivaloganathan, 1999). Unfortunately though, KRU in manufacturing organizations has been found to be considerably low, averaging only 28% (Ettlie & Kubarek, 2008). This ineffectiveness has researchers (Shahin, Andrews, & Sivaloganathan, 1999; Ettlie & Kubarek, 2008) pointing to a lack of robust KMS as being a significant barrier in KRU. Consequently, our survey data was sought from the following sources: (1) members of the Original Equipment Supplier Association's Warranty Management Council, (2) via the social networking website LinkedIn and its largest Knowledge Management, Automotive and Manufacturing groups, as well as (3) all relevant level 1 contacts the primary author's business contact lists. Following these efforts, the total number of responses obtained was 334.

Of the 334 surveys completed, 258 were identified as useable. The remaining 76 were discarded for either not passing the initial screening question, or for dropping out of the survey prematurely. Over half of the respondents were male (62%), and had more than 10 years of experience in their current profession (51%). Eighty-one percent of respondents had at least a 2 year college degree, and nearly half (49%) worked in organizations with more than 1,000 employees. Fifty-one percent of respondents came from traditional functional departments found in large organizations (i.e., Quality, Research & Development, Design, Production, Human Resources, Sales and Customer Service); however a number of respondents also came from independent consultants or third party consulting firms (30%). Finally, as previously mentioned, the manufacturing industry represented the highest sector of respondents with 36%, followed by other commonly found sectors in the EKR literature, i.e., the software and consulting industries at 10% and 9%, respectively. The remaining percentages were comprised of sectors such as: transportation, government, software, banking/finance (see Appendices B and C for more details).

In terms of relevant EKR demographics, the survey included 4 questions pertaining to experience and exposure. Interestingly, on average respondents reported that their organizations employed 3 EKRs, with an average current age of 3 1/2 years in service. Additionally, on average respondents reported using their company's EKRs for nearly 3 years, while having 4 years of overall EKRs experience. Table 2 below shows a further breakdown of these EKR demographics.

Table 2: EKR Demographics

EKR Experience Related Questions	**N (Samples)**	**Average**	**STD Dev.**

How many electronic knowledge repositories does your / company currently utilize?	192	3	1.3
Approximately how long has your company's electronic / knowledge repository(s) been in use?	264	3	1.0
Approximately how long have you been using your company's / electronic knowledge repository(s)?	264	3	1.1
Approximately how many years of experience do you have / using electronic knowledge repositories?	252	4	1.1

Finally, to determine where the knowledge from these EKRs was being reused, respondents were asked to document affected areas. As shown in Table 3, over 70% of respondents selected design and launch of new products and/or processes, training, continuous improvement and addressing customer issues (internal or external) as the areas where knowledge was being reused. In line with the theoretical benefits of KRU, the majority of reuse efforts were applied in areas where efficiency gains could be attained by reusing past solutions.

Table 3: EKR Experience and Exposure Survey Questions

Areas where knowledge is being reused	**N (Samples)**	**% of respondents**
Design and launch of new products and/or processes	194	73.5%
Training	192	72.7%
Continuous Improvement	188	71.2%
Address internal or external customer issues	187	70.8%
Other ('e.g. project management, material planning, e-req, etc.')	46	17.4%

Analysis and Modeling Approach

Since this study aims at extending the limited knowledge surrounding KRU via EKRs, the research relates closer to an exploratory vs. confirmatory analysis method. Hence, a prediction over explanation approach was selected, and Partial Least Squares and SmartPLS were chosen. Lacking theories that apply directly to a KRU via EKRs makes Partial Least Squares (PLS) a more suitable parameter estimation methodology (Chin, 1998; Haenlein & Kaplan, 2004), while SmartPLS allows the researcher to work with smaller sample sizes.

Several attractive features of PLS-SEM (Structural Equation Modeling) have led to increased usage in the areas of management, strategy, and marketing research (Sattler et al., 2010) and in regards to our study a number of these features apply. PLS-SEM has been identified as a so called 'soft modeling' approach (Wold, 1982), whereby it is less suited for testing well-established complex theories primarily because of a lack of global optimization criterion to assess overall model fit (Hair et al., 2012). Rather, PLS-SEM offers a predictive and theory building approach that yields robust estimations of the structural model (Hair et al., 2011). Hence, while we recognize causal explanatory modeling via Covariance Based (CB) methods can provide richer modeling mechanisms, better parameter estimates and can handle endogeneity to ensure unbiased estimates (Antonakis et al., 200), the lack of theory surrounding KRU via EKRs, and in particular the lack of a comprehensive view of this area lends itself to an initial predictive approach of PLS-SEM and theory building. Furthermore, Hair et al. (2012) suggest a follow-up complimentary effort using CB-SEM is wholly appropriate as a continuation and confirmatory approach to PLS-SEM. Finally, while our approach is predictive rather than causal, the following sections demonstrate the rigorous assessment still employed to validate our findings.

Measurement Model

To check the adequacy of the measurement model, an Exploratory Factor Analysis (EFA) was conducted followed by a Confirmatory Factor Analysis (CFA). Principal axis factoring with Promax rotation revealed an acceptable factor structure where KMO = 0.90, Bartlett's Test of Sphericity $\chi^2 = 8923.87$, df=1378, $p< 0.001$ and MSA's > 0.65. Communality values exceeded the 0.32 rule of thumb (Tabachnick and Fidell 2001) and all indicators loaded onto their hypothesized constructs except for two anomalies. One of the measures for KVP did not load onto the construct and one measure for KS loaded poorly, i.e., less than 0.3. Consequently, KVP was modified from a five- item to four-item scale, however KS was left intact because the overall construct had sufficient Construct Reliability (CR), i.e., > 0.70 (Hair Jr., Black, Babin, & Anderson, 2010). Next, CFA was conducted in the context of the PLS-SEM.

Confirmatory Factor Analysis: Validity and Reliability

A Confirmatory Factor Analysis (CFA) was done to verify that the factor structure to be used in structural modeling is both valid and reliable. *Convergent validity* is analyzed via the three standards recommended by Bagozzi and Yi (1988) to assess the measurement model: (1) all indicator CFA factor loadings should exceed 0.50 (Hair Jr., Black, Babin, & Anderson, 2010); (2) CR should be above 0.70; and (3) the Average Variance Extracted (AVE) of every construct should exceed (Fornell & Larcker, 1981). In Table 3 below, the values for these standard is provided. The factor loadings of all the items measure in the range of 0.60 to 0.92, thus meeting the threshold set by Hair et al., (2010) and demonstrating convergent validity at the item level. At the construct level, Hair et al. (2010) recommended that the CR should be used in conjunction with SEM to address the tendency of the Cronbach's alpha to understate reliability. Each constructs CR exceeds the 0.70 recommendation. The final indicator of convergent validity is the AVE, which measures the amount of variance captured by the construct in relation to the amount of variance attributable to measurement error (Fornell & Larcker, 1981). Convergent validity is judged to be adequate when AVE equals or exceeds 0.50. As seen in Table 4, the convergent validity for the proposed constructs is adequate.

Table 4: Summary of Results for Outer Models

Latent Variable	Indicators	Loadings	T-Statistic*	Indicator Reliability ($loadings^2$)	Composite Reliability	AVE
CONTINUANCE OF USE (CON)	CON1	0.906	5.161	0.821	0.890	0.677
	CON2	0.925	48.564	0.856		
	CON3	0.894	63.255	0.799		
END USER COMPUTING SATISFACTION (EUCS)	EUCS1	0.846	41.355	0.716	0.946	0.639
	EUCS2	0.806	30.703	0.650		
	EUCS3	0.820	34.681	0.672		

	EUCS4	0.763	21.671	0.582		
	EUCS5	0.829	31.691	0.687		
	EUCS6	0.844	37.147	0.712		
	EUCS7	0.749	19.779	0.561		
	EUCS8	0.757	22.219	0.573		
	EUCS9	0.754	20.469	0.569		
	EUCS10	0.817	28.031	0.667		
INFORMATION TECHNOLOGY SUPPORT (ITS)	ITS1	0.730	13.974	0.533	0.882	0.716
	ITS2	0.882	38.174	0.778		
	ITS3	0.916	73.777	0.839		
KNOWLEDGE REUSE (KRU)	KRU1	0.865	41.009	0.748	0.912	0.675
	KRU2	0.874	45.152	0.764		
	KRU3	0.800	19.911	0.640		
	KRU4	0.747	14.558	0.558		
	KRU5	0.817	23.284	0.667		
KNOWLEDGE SHARING (KS)	KS1	0.763	12.569	0.582	0.830	0.551
	KS2	0.785	12.865	0.616		
	KS3	0.757	12.236	0.573		
	KS4	0.660	7.265	0.436		
KNOWLEDGE VALIDATION PROCESS (KVP)	KVP1	0.763	15.131	0.582	0.848	0.584
	KVP2	0.711	12.633	0.506		
	KVP3	0.744	10.714	0.554		
	KVP4	0.833	27.812	0.694		
LEARNING CULTURE (LC)	LC1	0.781	29.145	0.610	0.900	0.643
	LC2	0.854	45.987	0.729		
	LC3	0.779	23.205	0.607		
	LC4	0.785	19.932	0.616		
	LC5	0.808	31.568	0.653		
PERFORMANCE (PER)	PER1	0.832	22.549	0.692	0.918	0.692
	PER2	0.831	36.922	0.691		
	PER3	0.851	36.741	0.724		
	PER4	0.831	28.752	0.691		
	PER5	0.813	24.618	0.661		
KNOWLEDGE MANAGEMENT STRATEGY (KMST)	KMST1	0.800	28.227	0.640	0.928	0.648
	KMST2	0.797	31.585	0.635		
	KMST3	0.795	25.782	0.632		
	KMST4	0.849	41.773	0.721		
	KMST5	0.806	32.814	0.650		
	KMST6	0.830	36.109	0.689		
	KMST7	0.752	20.665	0.566		
WORKER INTERATION AND COLLABORATION (WIC)	WIC1	0.661	7.920	0.437	0.833	0.558
	WIC2	0.692	10.117	0.479		
	WIC3	0.739	19.844	0.546		
	WIC4	0.866	7.611	0.750		

* p-value > 1.96 are significant @ 0.05 level.

Discriminate validity is assessed by comparing the square root of a construct's average variance extracted with that construct's correlations with the other constructs in the model. If the square root of the AVE is greater than the correlations with other constructs in the model (the offdiagonals in a correlation matrix[1]), then discriminate validity is demonstrated (Fornell & Larcker, 1981). As Table 4 shows each construct is more closely related to its own measures than to those of other constructs. Thus, the analysis results show evidence of sufficient discriminant validity. Finally, to examine the discriminate validity of the measurement model, the correlations among latent constructs were examined. High correlations exceeding 0.85 (Kline, 1998), should be noted as an indication of a problematic level of inter-correlated constructs. As shown in Table 5, no correlation among the latent constructs is greater than 0.61. Thus, the measurement model in this research shows satisfactory reliability, convergent validity, and discriminant validity.

Table 5: Correlations among Factors

	CON	EUCS	ITS	KRU	KS	KVP	LC	PER	KMST	WIC
CON	**0.91**									
EUCS	0.34	**0.80**								
ITS	0.22	0.49	**0.85**							
KRU	0.53	0.50	0.29	**0.82**						
KS	0.34	0.38	0.35	0.37	**0.74**					
KVP	0.19	0.33	0.09	0.25	0.16	**0.76**				
LC	0.32	0.55	0.44	0.45	0.51	0.33	**0.80**			
PER	0.50	0.56	0.36	0.58	0.26	0.23	0.43	**0.83**		
KMST	0.19	0.53	0.47	0.47	0.34	0.32	0.61	0.40	**0.81**	
WIC	0.29	0.20	0.14	0.34	0.33	0.04	0.39	0.24	0.24	**0.75**

Note: Diagonal elements are the square root of Average Variance Extracted. These values should exceed the inter construct correlations (off diagonal elements) for adequate discriminant validity.

Common Method Bias

The data collection method for the study was in the form of a self reported survey, thus both the dependent and independent variables were measured with the same instrument and hence the possibility of common method bias exists (Siponen & Vance, 2010). To address this, several efforts were taken to both limit and assess the impact of CMB in the study.

[1] Alternatively, AVEs (rather than their square root) can be compared against the squared term of each correlation.

Following the recommendations of Podsakoff et al. (2003), various procedural remedies were employed to reduce common method bias. To reduce the likelihood of socially desirable responses, respondents were informed of their response anonymity prior to the start of the survey. Next, to reduce order bias the survey questions were randomized. Finally, items were randomized to avoid disclosure of the underlying structural model.

Next, to statistically assess the impact of CMB three approaches were taken. First, Harmon's one factor test (Podsakoff et al., 2003) was conducted, of which no single factor accounted for more than 28% of the variance suggesting a lack of CMB. However, given Harmon's one factor test is increasingly contested for its ability to detect CMB (Podsakoff et al., 2003); an additional test as suggested by Pavlouv et al. (2007) was performed. The construct correlation matrix was examined to determine if any constructs correlate extremely high (> 0.90). As shown in Table 6, no constructs met this condition further supporting a lack of CMB.

The final test for CMB is a latent method factor test that was adapted by Liang et al. (2007) and suggested by Podsakoff et al. (2003). The results indicate that the average variance due to substantive constructs is 0.80, while the average variance due to the method construct was 0.0003. Additionally, the majority of method factor loadings were not significant. Given this, CMB does not appear to be a concern. The results of this test are summarized in the table provided in Appendix D.

Test of the Structural Model

The evaluation of the structural model was conducted by assessing the following metrics: Choen's (1988) coefficient of determination (R^2) and effect sizes $(f)^2$, Geisser (1975) and Stone (1974) estimated structural path coefficients and their significance levels, and Stone-Geisser $(Q)^2$

test for predictive relevance. Finally, to test for mediating effects of the model, the Preacher and Hayes (2004, 2008) procedure was followed.

Following Chin's (1998) guidelines, R^2 values of 0.67, 0.33, and 0.19 are considered to be "substantial", "moderate", and "weak" respectively. Additionally, in the case where an endogenous variable is predicted by only one or two exogenous variables, a moderate R^2 may be acceptable (Chin, The partial least squares approach to structural equation modeling, 1998). Finally, to test for significance of R^2, Falk and Miller's (1992) F-test is used. Table 5 summarizes the results of the R^2 and F assessment. All dependent variables are significant at the 0.01 level. Using Chin's (1988) R^2 guideline: PER, KRU, and LC qualify as "moderate".

Table 6: Significance test of dependent variables R^2values

			Critical F-values		
Dependent Variable	$\boldsymbol{R^2}$	***F-stat.***	***@ 0.05***	***@0.01***	***@0.001***
Continuance of Use	0.30*	54.903	3.031	4.688	7.096
Information Technology Support	0.24*	81.731	3.878	6.734	11.080
Knowledge Reuse	0.35*	22.924	2.134	2.872	3.880
Knowledge Sharing	0.07*	18.973	3.878	6.734	11.080
Knowledge Validation Process	0.11*	31.964	3.878	6.734	11.080
Learning Culture	0.43*	96.972	3.031	4.688	7.096
Performance	0.34*	128.962	3.878	6.734	11.080

* significant @ the 0.001 level

Next, effect size f^2 is calculated as an additional method to assess the explanatory power of the PLS model (Chin, 1998; Gotz et al., 2010). Essentially, the effect size measures the change in R^2 as a predicator latent variable is removed from the model. The f^2 values of 0.02, 0.15 and 0.35 respectively are used as guidelines for small, medium and large effect sizes of the predictive variables (Chin, 1988). The results of the full model show that the significant predictors of KRU explain approximately 35% (R^2 is 0.35) of the variance. The largest predictor for KRU is EUCS with a value of 0.30 at a significance level of $p < 0.000$. When EUCS is excluded from the model, the remaining predictors explain 30% (R^2 is 0.30) of KRU variance and the effect size is between small and medium, i.e., f^2= 0.08.

The Stone-Geisser Q^2 is another criterion for structural model assessment (Geisser, 1975; Stone, 1974), whereby values of Q^2 larger than zero for a certain reflective endogenous variable indicate the path model's predictive relevance for this particular construct (Hair Jr, Hult, Ringle, & Sarstedt, 2013). The predictive relevance of the model is then demonstrated for all endogenous variables when Q^2 is greater than zero and lacks predictive relevance when Q^2 is close to zero or negative (Chin, How to write up and report PLS analyses, 2010). As well, similarly to the f^2 effect size approach for assessing R^2values, the relative impact of Q^2can assessed by its q^2effect size (Hair Jr, Hult, Ringle, & Sarstedt, 2013). Similarly to f^2, values of 0.02, 0.15, and 0.35 indicate that an exogenous construct has a small, medium, or large predictive relevance for a certain endogenous construct (Hair Jr. et al., 2013).

The results of the Q^2, along with $R^2$of all endogenous constructs are provided in Table 7. Five of the seven constructs have Q^2 values considerably higher than zero, providing further support for the model's predictive relevance regarding these latent variables. However, KS and KVP are close to zero and in line with their corresponding low R^2values, lack predictive relevance.

Table 7: Summary of $R^2$and Q^2 Values

Endogenous Latent Variable	***R^2 Value***	***Q^2 Value***
Continuance of Use	0.30	0.236
Information Technology Support	0.24	0.168
Knowledge Reuse	0.35	0.224
Knowledge Sharing	0.07	0.029
Knowledge Validation Process	0.11	0.056
Learning Culture	0.43	0.271
Performance	0.34	0.221

Table 8 provides a final assessment that addresses f^2 and q^2 effect sizes. The f^2 can be considered large for KMST to LC, and small to medium for EUCS to KRU, KMST to KRU, WIC to KRU, and KS to CON. Correspondingly, q^2 can be considered large for KMST to LC and small to medium for WIC to LC, WIC to KRU, and KS to CON.

Table 8: Summary of Results (Path Coefficients, f^2, q^2)

	Learning Culture			***Knowledge Reuse***			***Continuance of Use***		
	Path coefficients	f^2	q^2	*Path coefficients*	f^2	q^2	*Path coefficients*	f^2	q^2
EUCS				0.301	0.078	0.041			
ITS				-0.019	0.000	-0.002			
KVP				0.051	0.003	0.000			
LC				0.082	0.008	0.001			
KMST	0.558	0.518	0.257	0.204	0.036	0.017			
WIC	0.242	0.099	0.048	0.195	0.050	0.026			
KS							0.224	0.064	0.047

Mediation Check

To test for mediating effects of the model, the Preacher and Hayes (2004, 2008) procedure was followed. The procedure itself is a two-step process where firstly the direct effect without the mediator is assessed for significance. If the effect is not significant than there is no mediating effect, however if it is significant then the mediating variable is added to the model and then bootstrapped to determine the significance of the indirect effect. If the indirect effect is not significant then there is no mediation, however if it is, then the amount of the mediator's direct effect is assessed through an index (Variance Accounted For, VAF). As Hair Jr. et al., (2013) explain, VAF is simply the ratio of size of the indirect effect in relation to the total effect (VAF > 80%, Full Mediation; 20% ≤ VAF ≤ 80%, Partial Mediation; VAF ≤ 20%, No Mediation).

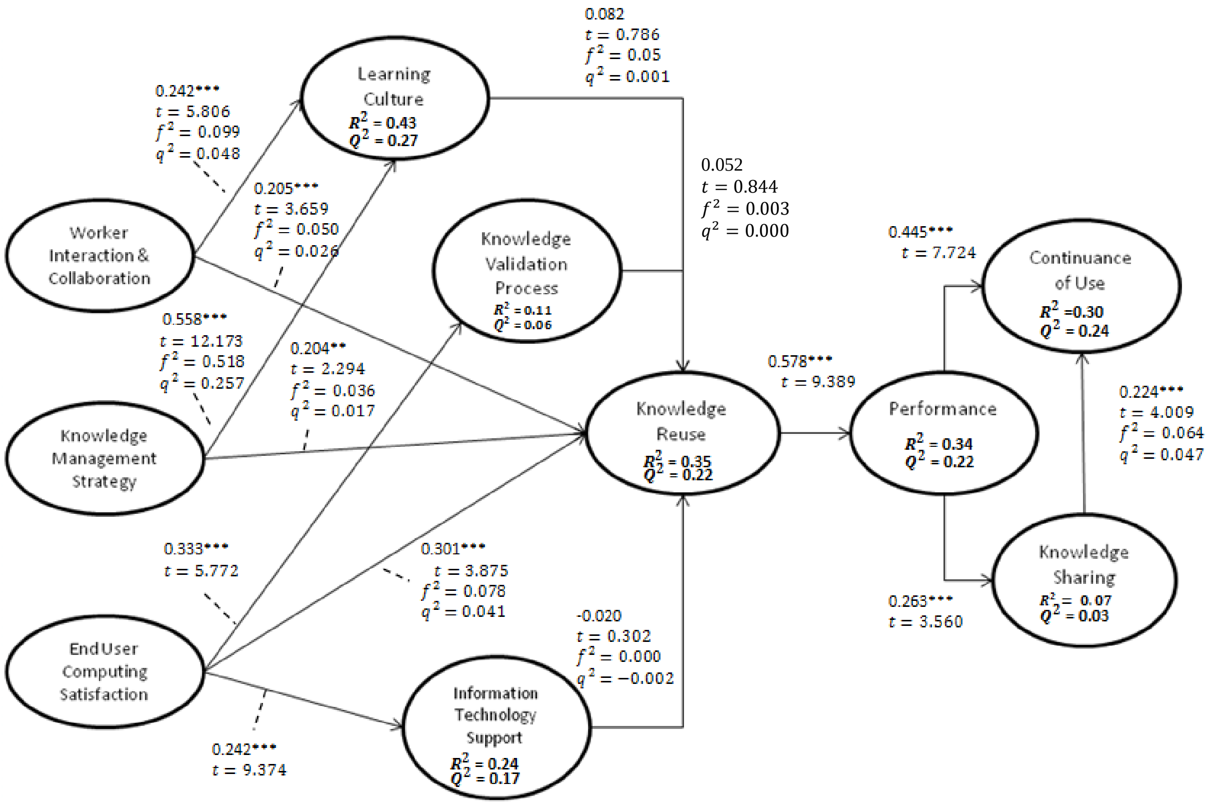
The significance of path coefficients without their respective mediator variables are provided in Table 9. Given the significance of the direct effect less the mediator, a look at the corresponding indirect effect follows.

Table 9: Significance Analysis of Path Coefficients Without Mediator			
Path	Path Coefficient	T-Statistic	P value
WIC → KRU	0.206	4.370	0.000
KMST → KRU	0.242	3.168	0.002
EUCS → KRU w/o KVP	0.314	4.112	0.000
EUCS → KRU w/o ITS	0.298	3.789	0.000
PER → CON	0.506	10.278	0.000

The assessment of the indirect effects of the mediating variables is provided in Table 10. Only the PER → KS → CON path was significant at the 0.10 level, however since the corresponding VAF value is only 11.7%, we consider this effect to be negligible, or has no mediation. Hence, the mediation test results refuted the influencing effect of these mediating variables on the model.

Table 10: Summary of Mediation Results					
Path	T-Statistic	P-Value	Significance	VAF	Mediation
WIC → LC → KRU	0.932	0.351	No	-	None
KMST → LC → KRU	0.881	0.378	No	-	None
EUCS → KVP → KRU	0.193	0.847	No	-	None
EUCS → ITS → KRU	0.147	0.883	No	-	None
PER → KS → CON	1.908	0.056	@0.10 level	11.7%	None

Shown in Figure 4 are the path coefficients and their corresponding *t*-values and significant levels estimated using a PLS bootstrap method where n=5000. Additionally, R^2 values are provided for dependent variables, and f^2 and q^2 values are provided for applicable path coefficients.



***p<0.001, **p<0.01, *p<0.05, '----' (used to highlight corresponding path)

Figure 4: Structural Model Results

Table 11 summarizes the results of the analysis and the extent to which the research hypotheses are supported.

Table 11: **Summary of Research Hypotheses**		
Hypotheses	**Finding**	**Conclusion**
H1 *– End User Computing Satisfaction (EUCS) positively influences KRU through electronic repositories.*	**Yes**, β = 0.301, p=0.000	**Supported**
H2a *– Information Technology Support (ITS) positively influences KRU through EKRs.* ***H2b*** *- ITS mediates the influence of EUCS on KRU through EKRs.*	No, β = -0.002, p=0.763 No mediation	*Not Supported* *Not Supported*
H3 *Worker Interaction and Collaboration (WIC) positively influences Knowledge Reuse (KRU) through Electronic Knowledge Repositories (EKRs).*	**Yes**, β = 0.205, p=0.000	**Supported**

H4 *– Knowledge Management Strategy (KMST) positively influences KRU through electronic knowledge repositories.*	**Yes**, β = 0.204, p=0.022	**Supported**
H5a *– Learning Culture positively influences KRU through EKRs.* ***H5b*** *– LC mediates the influence of WIC on KRU through EKRs.* ***H5c****– LC mediates the influence of KMST on KRU through EKRs.*	No, β = 0.082, p=0.153 No mediation No mediation	*Not Supported* *Not Supported* *Not Supported*
H6a *– Knowledge Validation Process (KVP) positively influences KRU through EKRs.* ***H6b*** *– KVP mediates the influence of EUCS on KRU through EKRs*	No, β = 0.052 p=0.399 No mediation	*Not Supported* *Not Supported*
H7 **-** *Knowledge Reuse (KRU) through positively influences worker Performance (PER)*	Yes, β = 0.578, p=0.000	**Supported**
H8a *– PER positively influences Continuance of use (CON) of EKRs.* ***H8b*** **-** *PER positively influences Knowledge Sharing (KS).*	Yes, β = 0.445, p=0.000 Yes, β = 0.263, p=0.000	**Supported** **Supported**
H9a*– KS positively influences CON of EKRs* ***H9b*** *– KS mediates the influence of PER on CON of EKRs.*	Yes, β = 0.224, p=0.000 No Mediation	**Supported** *Not Supported*

Discussion

Given the aforementioned lack of understanding surrounding KRU via EKRs, our study was the first attempt to empirically broaden the discussion to include both antecedents and resulting outcomes. Firstly, organizational factors WIC and KMST are both key players in predicting KRU through EKRs. In the case of WIC, organizations that have or can create an environment where interaction and collaboration is common place; increase the amount of knowledge reuse that occurs through their EKRs. Logically, this finding is intuitively sound in that as workers interact and collaborate with one another it can be expected that they would exchange ideas and recall, or lead their peers to knowledge that would reside in their organizational EKRs. Theoretically, this interaction appears to be an ancillary benefit of knowledge transfer and the tacit dimension of knowledge in that it appears to influence knowledge seekers attitudes towards the reuse of existing knowledge. Additionally, the finding also suggests a parallel notion that not only can modern organizations effectively extend their potential to create knowledge by focusing on interaction with others (Perez-Bustamante, 1999), but they can also impact KRU through EKRs by employing similar types of interacting routines. In terms of KMST, the impact of leadership on recognizing the importance of knowledge and strategically aligning it to the business objectives is another important factor in influencing KRU through EKRs. Essentially, if organizational leadership does not identify or support knowledge management as a key initiative, then it will likely fail. Additionally, if leaders do not design systems and procedures as reinforcement mechanisms they run the risk of weakening their message from the onset (Schein, 2010). Next, given that EKRs are devices requiring user interaction, it is imperative that users are satisfied with them. Not surprisingly then, EUCS was found to have a significant predictive relationship with KRU. In effect, if the tool a user employs to access knowledge is too cumbersome, difficult to use, inaccurate, or irrelevant, then it stands to reason that the user will eventually forgo or minimize usage of said tool. Thus, when designing an EKR it is critical to evaluate its ability to satisfy the needs of its users, and not only at initial launch, but throughout its life in order to continually improve it; thereby keeping it relevant and enhancing its desirability, and usage.

Conversely, ITS, LC, and KVP did not exert an influence on KRU through EKRs, neither from a direct or mediating standpoint. In the case of ITS, while it did not have a direct predictive impact on KRU, it was significantly related to EUCS. Thus, ITS may play an indirect role in KRU in that as more ITS is provided, EUCS increases, which in turn directly influences KRU. Unlike Durcikova and Gray's (2009) finding regarding the positive influence KVP played in knowledge contribution, this study did not identify a statistically significant link between KVP and KRU. Instead, KVP appears to play a similar role to ITS, in that while it did not directly predict or mediate KRU, it also had a significant path loading with EUCS. This relational link suggests that issues with EUCS influence KVP. Not coincidentally, this finding falls in line with the KM literature that holds that stringent validation processes will have a beneficial impact on the quality of the knowledge within a repository, thereby enhancing its value to knowledge seekers (Markus, 2001; Offsey, 1997; Zack, 1999). Similarly then, KVP may also play an indirect role in KRU in that as KVP is used to enhance EUCS, this in turn increases the predictive power of EUCS on KRU, thereby increasing KRU. Finally, LC exhibited a similar behavior to ITS and KVP in that while it did not have a direct or mediating impact on KRU, it did have a significantly high loading with KMST. Hence, given that KMST predicts LC, LC may be indirectly impacting KRU by influencing KMST, which in turn influences KRU.

In terms of the resulting outcomes of KRU through EKRs, the strongest path coefficient in the model exists between KRU and PER. This findings supports that of Kankanhalli et al. (2011), who also reported a similar positive influence of KRU on PER. Thus, the importance of KRU through EKRs cannot be understated given its relationship to performance, i.e., organizations will benefit from a performance standpoint by reusing the knowledge located within EKRs. Additionally, PER has a significant effect on KS and CON. PER was found to predict both KS and CON, thereby providing additional organizational benefits beyond that of its primary performance outcome. In this case, PER appears to play a reinforcing role in that as KRU is applied and PER benefits are realized, this in turn influences greater KS and as well as CON. This is a key finding in that the effect of KRU on PER creates a sustainable cycle for CON. In closing, the results of the study play a pivotal role in helping to better understand the factors that impact KRU through EKRs. Reiterating Markus (2001), successful knowledge reuse is not simply providing access to information technology and repositories, it requires a systemic effort that starts with leadership and permeates it way through the organization.

Theoretical Implications

The primary theoretical contribution of this study is the extension of extant research models into a comprehensive view of KRU that includes a front end impacting, and back end resulting outcome view. The front end piece is informed via the Socio-technical theory and several socio and technical factors are used to represent it. In particular, the impact of EUCS on KRU cannot be understated and supports the necessity to marry both social and technical factors within the EKR environment in order to close what Whitworth (2006) described as a social-technical gap, i.e. computers not doing what user's want them to. By building a system led by strategy and interconnected with organizational interacting routines, the resulting system becomes more social and helps to close this gap. Thus, from a theoretical perspective our findings strengthen the need to view EKRs or KMSs in the context of socio-technical systems, and reach what Whitworth (2006) describes as 'higher system – level needs' that integrate the norms, cultures and sociology of the organization within the mechanical / hardware piece. In other words, to predict greater likelihood of KMS success the software / people aspect of the system must be adequately balanced with it's the hardware / architectural piece. Next, the research is also the first to integrate and empirically examine KRU and CON in an interconnected manner to empirically validate the backend, or resulting outcome aspect of KRU and its benefits beyond performance. Our findings indicate that the connection between an outcome indicator, i.e. KRU in this case, and subsequent outcome factors consistently reflects the ECM approach, and hence is a useful framework for future technological tie-ins beyond that of EKR and KMS fields.

Another unique finding of this study is the relative newness respondents had to EKRs. While the EKR literature extends back more than a decade, on average respondents did not report any more than 3.5 year's worth of EKR usage. This suggests that although this field has received some attention from the academic community, it is still early on in its lifecycle. This revelation may lead others to continue tilling this land, ultimately leading to fruitful bounties for both research and practice. Specifically, additional theories from the learning field may help to further shape and refine the model by informing early learning and or temporal component considerations. Finally, this study is one of few empirical efforts in this field to make use of social media tools to enhance its respondent pool. The use of major sites such as LinkedIn, with its vast, diversified and pertinent communities, opens up a new and viable channel to non-experimental researchers to reach potential respondents. Additionally, by employing simple filtering techniques, pools of unique candidates can become available for researchers. In the case of this research, by testing the research model through respondents in this broader setting, the study represents the first attempt to empirically examine EKR behavior through social media tools. This approach offers researchers a new way of investigating research questions pertaining to EKRs, along with an efficient and effective mechanism to do so.

Practical Implications

From a practical standpoint, the research presents a number of pertinent and actionable recommendations. First, from an organizational standpoint, recognition of knowledge management as a key component to a company's strategic business plan and providing top management support in operationalizing that strategy is a significant predictor of KRU through EKRs. As Schein (2010) indicates, the beliefs, values and assumptions of organizational founders/leaders, play the most crucial role in establishing organizational culture. Organizational leaders are called upon to not only establish strategy, but are also the best weapon in retaining valued talent (Jamrog, 2004; Taylor, 2004) and clearly establishing the importance of knowledge to the organization's operation (McCann & Buckner, 2004; Mitch Casselman & Samson, 2007). Without this type of leadership involvement, the practices and routines necessary to develop, implement and continually support EKRs will not firmly take root. Next, WIC was shown to influence KRU through EKRs, and hence is another construct with which organizations can use to leverage greater KRU. Here, organizations can look towards strategies and tactics to enhance greater work force interaction and collaboration. Some examples include using technology to help foster discussions and communications, or establishing 'knowledge cafes', i.e., events where individuals or even other organizations can come together to engage in knowledge sharing, learning and innovating (Gurteen, 2015). Additionally, companies can also ensure that their key business processes are integrated to include interaction with other pertinent functional departments. Next, from a technical standpoint, the design of the EKR is a key contributor to KRU. Organizations can then look to assess their existing repositories and work towards enhancing them to impact greater KRU. In particular, technological impacts that can be used to improve the components of EUCS, i.e., Content, Accuracy, Format, Ease of Use and Timeliness will have a greater impact on KRU. For example, to improve ease of use, companies can look towards improving Graphical User Interfaces to mimic the traditional and ubiquitous search engines that are popularly employed on the web. Additionally, mechanisms that can allow for simpler knowledge contribution while maintaining an element of screening to ensure accuracy and applicable content can also improve EUCS.

Conclusions

Our timely research contributes to both the growing industrial movement as well as academic interest in KM and in particular KMS and EKRs. First, we developed and tested a multi – theoretical and sequentially complete model for KRU via EKRs. This broader view of KRU expands upon the localized views found in the literature and is the most complete assessment to date of KRU via EKRs. Second, we validated the use of the socio-technical perspective to inform the front end piece of KRU, and also identified several factors that predict greater KRU. Having justified the use of the perspective and identified factors that predict KRU, future studies can look to build upon our efforts and identify additional factors that may also play a role in KRU. Third, we validated the use of the ECM perspective to model the back end, resulting outcome view of KRU. Additionally, through this effort we developed a useful framework to study CON through an application's outcome measure of interest. Finally, we offer numerous industry suggestions as well as directions for future research to help guide others to continue to contribute to this growing area of interest. As we mentioned in our introduction, greater industry movement towards KMS and EKRs is inevitable, and hence research needs to continue along this path to help shine the way for others to follow.

CHAPTER 3: A DESIGN AND PROCESS BASED ONTOLOGY FOR ENHANCING MANUFACTURING EKRS

Introduction

Knowledge Management Systems (KMS) are IT based information systems intended to support and enhance an organization's ability to manage knowledge (Alavi & Leidner, 2001). An increasingly popular form of KMS are Electronic Knowledge Repositories (EKR). EKRs are defined as electronic storage locations where organizations have decided to maintain knowledge (Liebowitz & Beckman, 1998). These repositories are useful sources for Knowledge Reuse (KRU) in that they can provide codified expertise at times of need while helping to mitigate potential problems and provide greater business efficiency by not having to reinvent solutions (Akgun et al., 2005). Although various efforts have been taken to understand EKR usage (Kankanhalli et al., 2005a; Kankanhalli et al., 2005b; Watson & Hewett, 2006; He & Wei, 2009; Kankanhalli et al., 2011), gaps still exist pertaining to the enhancement of EKRs themselves. This is a considerable deficiency given Information Technology has played a positive role on knowledge sharing and knowledge application (Choi et al., 2010). An area where EKR enhancement can be particularly beneficial is the design and manufacturing industry. Here, researchers have indicated that growing information complexity (Lin et al., 2011), inconsistent terminology (Lin & Harding, 2007; Lin et al., 2011), insufficient information retrieval tools (Iyer, Jayanit, Lou, Kalyanaraman, & Ramani, 2005; Li, Yang, & Ramni, 2009), and a lack of widely accessible knowledge repositories (Chandrasegaran, et al., 2013) all represent significant challenges to knowledge sharing. The end result is that only 28% of design knowledge is being reused (Ettlie & Kubarek, 2008). This alarmingly low figure becomes further complicated when considering the globalization of manufacturing and the massive challenges associated with sharing distributed knowledge among various levels of expertise. Fortunately, ontologies have been identified as a tool that can address these issues, largely in part for their ability to share information within a particular domain (Swartout et al., 1996; Studer et al., 1998; Noy & McGuinness, 2001; Lin & Harding, 2007). Making use of the Semantic Web, its framework and tools allow data to be shared across applications, enterprises and community boundaries (W3Ca, 2014). To that end, this paper presents a Resource Description Framework (RDF) based ontology that merges key concepts from the design and process domains to provide a detailed, high resolution and interrelated representation of design and manufacturing knowledge. While a number of ontological efforts have been pursued in this field, they tend to fall into three categories, broader manufacturing enterprise based efforts (Lin et al., 2004; Lin & Harding, 2007; Lin et al., 2011), and design (Kitamura & Mizoguchi, 2004; Kim et al., 2006; Chang et al., 2010) and failure mode based efforts (Lee B. , 2001; Laaroussi et al., 2007; Ebrahimimpour et al., 2010; Molhanec et al., 2011; Zhao & Zhu, 2012; Dittmann et al., 2004). What is missing from these efforts is a relatable industry informed ontology that merges and interconnects key concepts from both the design and process domains. While recent failure mode or FMEA (Failure Mode and Effects Analysis) based efforts usefully map causal failure linkages, the current efforts lack completeness and in particular a strong connection between design and process knowledge. Hence, we introduce the DPFO or Design and Process Functional Ontology to bridge this gap by merging design and process functional requirements with their respective failure modes and associated controls to provide a more complete interconnect of key concepts within these domains. Consequently, the resulting ontology is to the best knowledge of its author, the most detailed representation of ontological design and process knowledge to date. Additionally, a systematic and constructive approach to the ontology development is provided to inform industry practitioners and enhance the ontology's overall usage. The rest of this manuscript is organized as follows. Section 2 reviews related literature. Section 3 describes the methodology for ontology development and utilization. Finally, Section 4 provides concluding remarks and directions for future research.

Literature Review

Ontologies

An ontology is defined as an 'explicit formal specification of a shared conceptualization' (Borst, 1997). Studer et al. (1998) help to clarify this definition by explaining that the term 'formal' refers to the necessity of the ontology to be machine readable, i.e., in a format that can be understood by a computer, while 'explicit specification' indicates that the concepts need to be explicitly defined, and 'shared conceptualization' requires that the ontology represents consensual knowledge of real world phenomena. A simplistic translation of this definition is that ontologies represent consensual, explicit knowledge in a manner that is machine-readable. As interests in ontologies have grown, they have moved beyond the realm of computer science and onto the desktop of domain experts (Noy & McGuinness, 2001). This increase in popularity can be derived in large part due to their ability to share information within a particular domain (Swartout et al., 1996; Studer et al., 1998; Noy & McGuinness, 2001; Lin & Harding, 2007). Prior to the development of ontologies, knowledge bases were difficult to share or re-use even when expressed in the same formalism and covering the same domain, a problem ultimately stemming from a lack of a shared terminology and structure for the knowledge bases (Swartout et al., 1996). Additionally, this issue is further amplified from an organizational standpoint as knowledge is often distributed not only functionally, but geographically. As Desouza & Evaristo (2003) indicate, knowledge is often spread over a wide spectrum and is meshed in a broad context. This makes the challenge of managing knowledge and in particular gaining from knowledge reuse quite difficult. Fortunately, by utilizing ontologies, isolated, fragmented and unrelated knowledge can be transformed into interrelated, systematic and structured knowledge; ultimately making it useable and searchable (Zhao and Zhu, 2012). As Niles & Pease (2001) indicate, this avoids having to re-invent the wheel with better integration and maintenance of existing knowledge. With the advent of the Semantic Web and its ontology friendly architecture, the potential for greater knowledge sharing increases significantly.

Semantic Web, RDF, OWL and SPARQL

The Semantic Web is described by the World Wide Web Consortium (W3C) (W3Ca, 2014) as a web that provides a common framework which allows data to be shared and reused across applications, enterprises and community boundaries. The data model behind this machine processing is known as Resource Description Framework (RDF) and RDF Schema (RDFS). RDF and RDFS can be appreciated for their ability to represent information in a simple, parsimonious and meaningful manner and were consequently selected as a recommendation by the W3C over incumbents like XML and XMLS (Lee B. T., 1998). The basic unit of information for RDF is known as a triple and consists of a *subject*, *predicate* and an *object* (Ducharme, 2013). RDFS is a vocabulary that adds semantics to this data, e.g. describing properties and classes. By combining multiple triples through the use of RDF and RDFS, complex representation of knowledge can be achieved, ultimately forming the structural basis of the Semantic Web (Maedche & Staab, 2001). Conversely, while the majority of data underlying the Web is stored in Relational Databases where a proven track record for scalability, efficient storage, query execution and reliability is offered, RDF is more expressive and can be interpreted, processed and reasoned by software agents (Sahoo, et al., 2009). Additionally, ontologies also provide a restriction-free framework that represents a machine readable reality on the Web, this allows information to be explicitly defined, shared, reused or distributed and hence is making it more widespread in the community (Martinez-Cruz, Blanco, & Vila, 2012). Next, accompanying the release of RDF was OWL, or Web Ontology Language.

OWL extends upon RDFS by providing further semantics in a machine-readable language that allows for inferences and interoperability across applications (Bechhofer, et al., www.w3.org, 2004). OWL was designed for use by machines i.e., it is not intended for human consumption, in order for applications to interpret the underlying data structure of the ontology (W3C, 2012). However, to assist with human interpretation of OWL, various forms of syntax are available, e.g. turtle format (Ducharme, 2013). OWL has subsequently been upgraded to OWL 2 to provide additional syntax and semantics (Bechhofer, et al., www.w3.org, 2012). Finally, the query language known as SPARQL was introduced as a W3C recommendation (W3Cc, n.d.) to accompany the semantic data model and language.

SPARQL is a recursive acronym for SPARQL Protocol and RDF Query Language (Ducharme, 2013). Given RDF data is organized as graphs, SPARQL can be considered a graph-matching query language which asks for pieces of information from a subset of data that meets specified conditions. Ontologies can then be structured in RDF, presented in OWL and queried via SPARQL for greater exposure and machine interoperability. Evidently then, the use of these tools can be combined to enhance EKRs. Consequently, we will develop a holistic design and process ontology by consulting a mature industry standard which we will then operationalize via the aforementioned Semantic Web tools. The selected standard comes from the automotive sector and is known as Advanced Product Quality Planning, or APQP (AIAG, 2008a).

Advanced Product Quality Planning

APQP is a structured method for defining and establishing the necessary steps to ensure that a product is planned and launched effectively to satisfy customer needs (Bobrek & Sokovic, 2005).

It was collectively developed by U.S. automakers Chrysler, Ford Motor Company, and General Motors to communicate product quality planning requirements to their supply base, and was released via a common reference manual in July 1994 (Thisse, 1996). Essentially, the goal of APQP is to facilitate communication with all parties involved to ensure that required steps are completed correctly and on time (Bobrek & Sokovic, 2005). The APQP process consists of five phases (AIAG, 2008a): (1) Planning and Defining the Program, (2) Product Design and Development, (3) Process Design and Development, (4) Product and Process Validation, and (5) Feedback, Assessment and Corrective Action. Visually, these phases are shown in Figure 5 below.

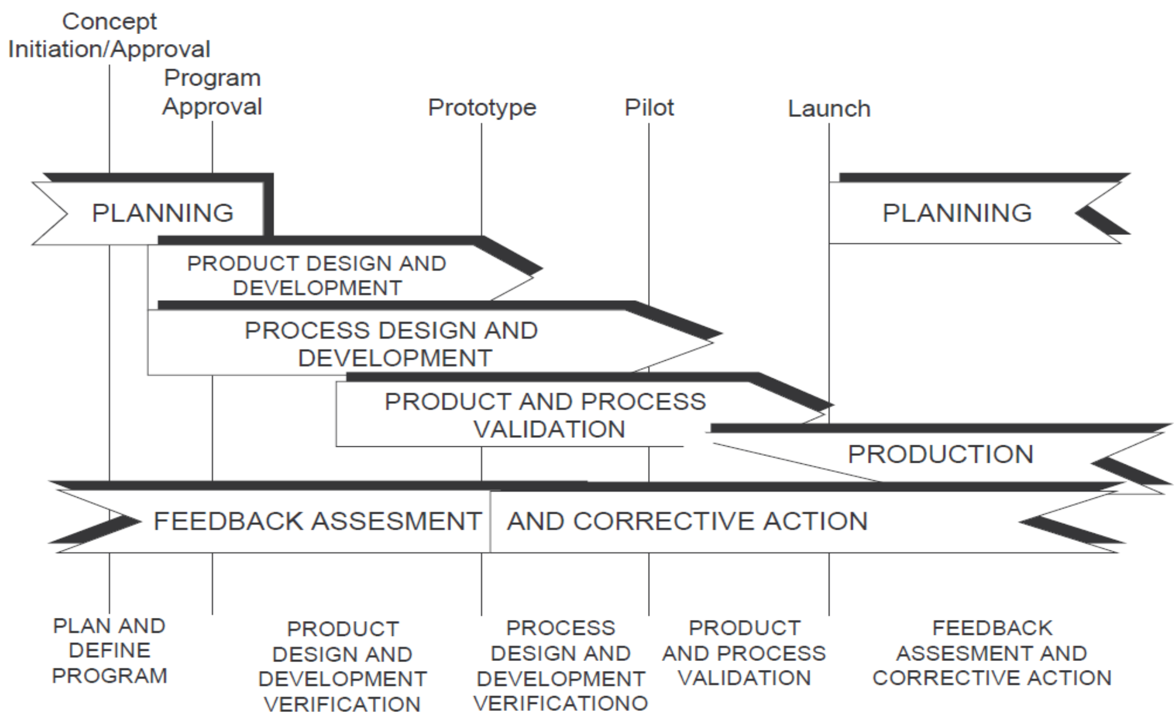


Figure 5: The five phases of the APQP process **(Bobrek & Sokovic, 2005)**

The APQP process blends both design and process knowledge to help improve the likelihood of a successful product launch. The knowledge from this process is primarily captured within four documents, i.e. the DFMEA or Design Failure Mode and Effects Analysis, PFMEA or Process Failure Mode and Effects Analysis, Process Flow, and Control Plan. These documents reflect both design and process knowledge and are considered living documents that can be used for knowledge management (AIAG, 2008a; AIAG, 2008b). Although the documents are created, stored and managed electronically, there are fundamental issues limiting their effectiveness. Firstly, they are created via natural language and are consequently plagued by both syntactical and semantic errors. Secondly, the documents and consequently the knowledge residing within them exist independently of one another with no unifying structure to bind them. Finally, they are product and/or process specific thereby limiting their ability to represent a particular domain of interest. Hence, by utilizing ontologies and the Semantic web, we will be able to bridge these gaps and provide a more complete and interconnected representation of the knowledge within this domain. Figure 6 below provides examples of the APQP documents.

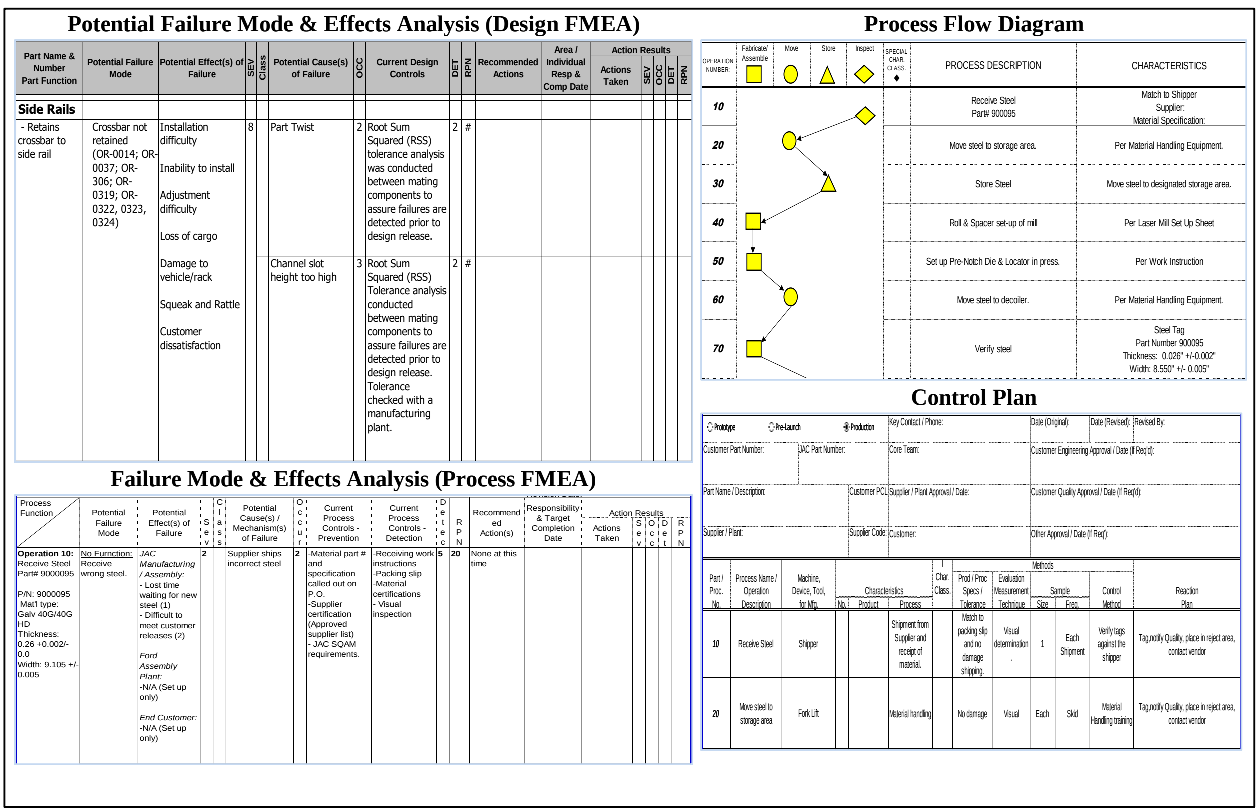


Figure 6: Examples of DFMEA, Process Flow Chart, PFMEA and Control Plan

Methodology for Ontology Development and Operationalization

While a number of ontology development methods exist in the literature (Uschold & King, 1995; Fernandez-Lopez, Gomez-Perez, & Juristo, 1997; Noy & McGuinness, 2001; Pinto & Martins, 2004; Ahmed, Kim, & Wallace, 2007; Sanya & Shehab, 2015) they stop short of describing the actual processes of operationalizing and utilizing the ontologies themselves. These last two steps are necessary for the actual usage of ontologies and without them they ultimately lack utility. As Agyapong-Kodua et al. (2013) indicate, ontology frameworks typically do not describe the pre and post-development phases of ontology design activities. Hence, our proposed ontology aims to close this gap by being both systematic and functional. From a systematic standpoint, the sequence follows a logical flow whereby the ontology is initially conceptually developed, formalized, published and then finally utilized. Functionally, by including the processes of operationalization and utilization, the ontology's utility is realized as it moves from initial concept through actual usage. These final two steps are considered key for industry adoption in that the conceptual effort is manifested into a functional application for employment. Finally, while Noy and McGuinness (2001) comment that the process for building and extending ontologies can take multiple approaches and hence there is no single correct procedure, we believe that in order to increase further adoption of ontology usage, the process of realizing them in a functional manner is a necessary requirement. The remainder of this paper is organized to present the systematic construction and utilization of the ontology per our proposed methodology. Figure 7 below visually displays the steps that comprise the methodology.

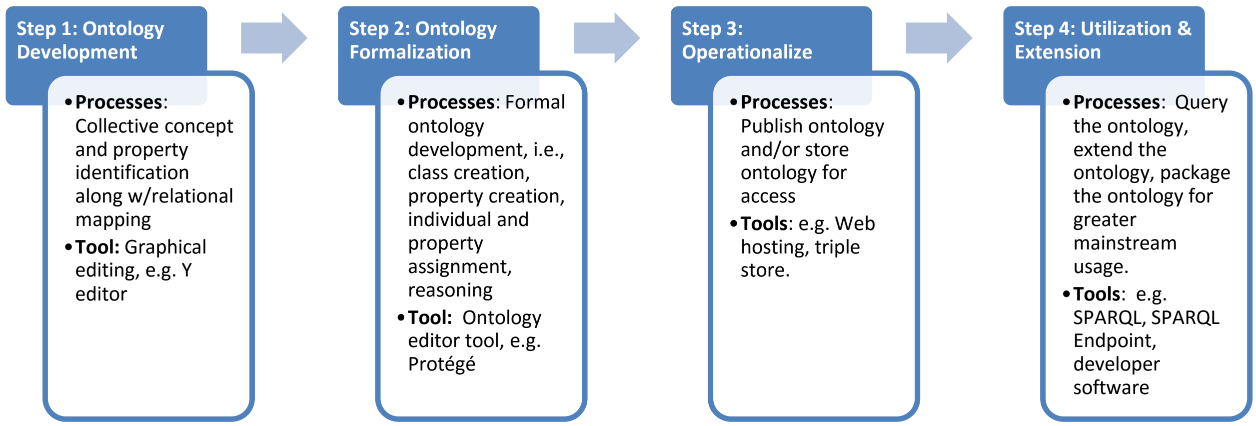


Figure 7: Methodology for ontology development and utilization

Ontology Development - High Level Concept Mapping

To develop our ontology, we employ an iterative *Waterfall* feedback approach (Royce, 1970), where concepts are identified within each of the APQP documents and then relationally mapped to pertinent others in each subsequent document. Given our ontology includes concepts from the failure centric or FMEA domain, we borrow concepts and associated properties from existing efforts to help inform our approach. Moreover, given the need for the ontology to represent a 'shared conceptulization' (Borst, 1997), as previously mentioned, the concepts from the ontology are taken from the mature APQP framework which was collectively developed by a consortium of automotive manufacturers and their suppliers (AIAG, 2008a). Additionally, following the recommendations of Sanya and Shehab (2015), we employ a modular approach to the ontology development to help compartmentalize and reduce the complexity within the various branches of the ontology. Consequently, the main branches of the ontology will be described individually, however will be pulled together via their interdependent limbs to provide a holistic view of the domain. Finally, using a second iterative pass, the concepts and their relationships are reviewed via a top down and bottom up approach to ensure consistency within the mappings.

Once all concepts are identified, the freely available graph-editor software yEd graph editor (yWorks GmbH, 2015) is employed to visually display the ontology. At this point, we halt the development effect to cover some basic components of ontologies to inform the subsequent discussion. First, *classes* are the primary focus of ontologies and are used to describe the concepts within the ontology's domain (Noy & McGuinness, 2001). Classes may have sub-classes that represent more specific classes of the preceding, or upper class. For example, a subclass of class 'Car' might define a specific type of car, e.g. compact, sport, economy, full size, etc. Next, *individuals,* are used to represent entities within the *classes* (Horridge, Knublauch, Rector, Stevens, & Wroe, 2004). For example, an *individual* of *class* Person could represent a person, e.g. 'Peter'. Next, *properties* are used to define binary relations between individuals (Horridge, Knublauch, Rector, Stevens, & Wroe, 2004). The two primary types of properties are *Object Properties*, and *Data Properties*. *Object Properties* are used to connect individuals between classes. For example, consider the simple mapping in Figure 8 below. Here we see two individuals from separate classes (*Peter* belonging to a class 'Person' and *Corolla* belonging to class 'Car') connected via the object property, 'HasCar'.

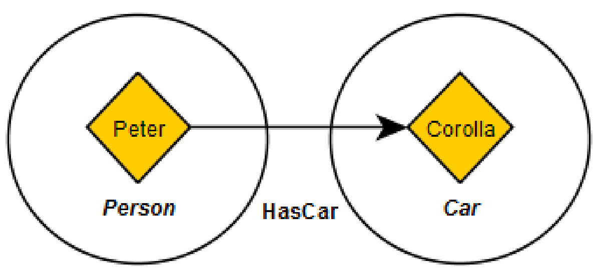


Figure 8: Simple mapping between individuals of classes

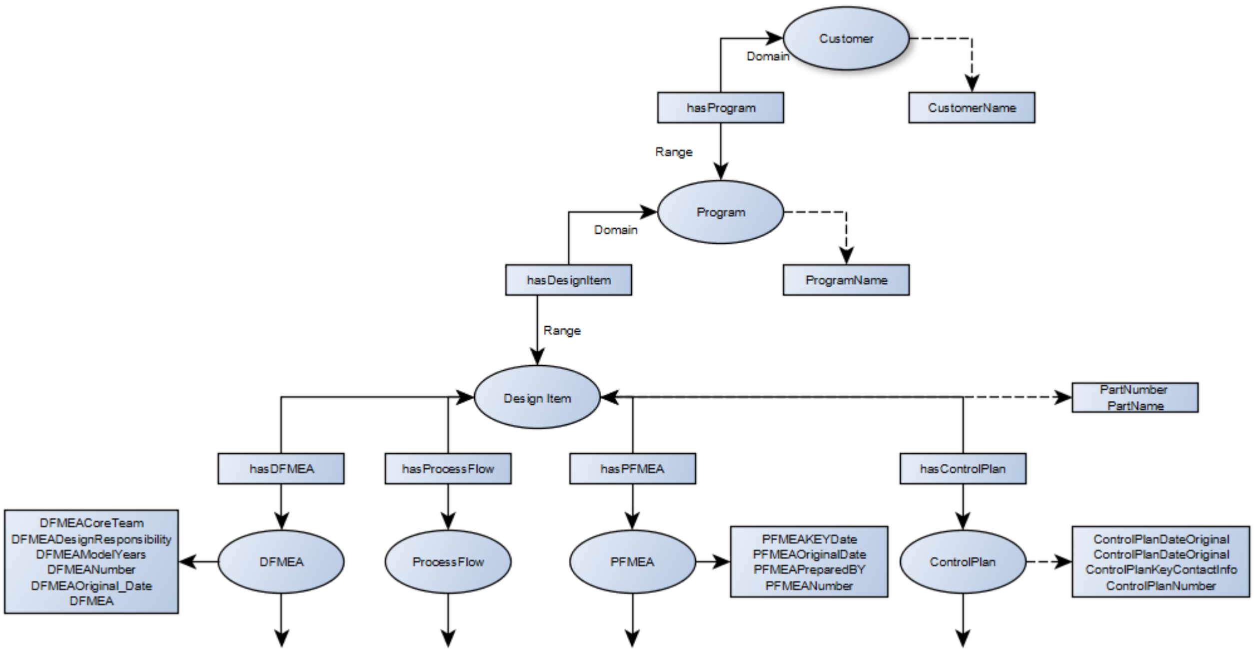
This mapping represents an RDF triple in that the subject is Peter, the predicate is HasCar, and the Object is Corolla:

$$(s, p, o) = (Person, HasCar, Car)$$

Next, *Data Properties* are used to link an individual to an XML Schema Datatype value, or an

RDF literal (Horridge, Knublauch, Rector, Stevens, & Wroe, 2004). Functionally, data properties are used to assign a particular type of value to an individual. These types of values can be strings, integers, boolean, etc. For example, referring back to Figure 5 above, a data property that may be associated to the individual 'Peter' could be of type string, and called 'name'. Finally, properties should have a *domain* and a *range* to specify the classes to which they belong. Referring again to the simple mapping example in figure 5, the object property 'HasCar' has a domain of class *Person* and a range of class *Car*, i.e. the property connects individuals from the domain of class *Person* to those individuals from the range of class *Car*. These basic components are used to formally construct the conceptual map for our design and process ontology.

The top level of the ontology begins with *class* 'Customer' and is connected to the *class* 'Program' via *object property* 'hasProgram'. From here, *class* 'Program' is then connected to *class* 'DesignItem' via the *object property* 'hasDesignItem'. At this point, *class* 'DesignItem' is then tied to the *classes* of 'DFMEA', 'ProcessFlow', 'PFMEA', and 'ControlPlan'. As shown in Figure 9 below, these linkages begin to establish the high level design and process knowledge assignments for their respective design items and associated programs and customers.



Legend (Typ.)

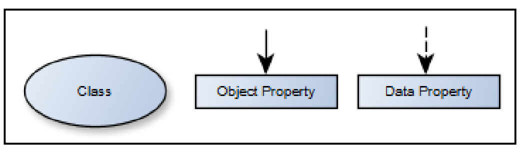


Figure 9: Design and process manufacturing ontology development: High level concept map

Ontology Development - Design Concepts Branch

Next, the focus shifts to the design branch and the associated connections within it. Here, the primary connection to *class* DFMEA begins with *class* Design Function. This connection establishes the linkage between the design item, its functions and its associated potential design failure modes. The *class* 'PotentialDesignFailureMode' is then connected to corresponding *classes*, 'PotentialCauseofDesignFailureMode', and 'PotentialEffectofDesignFailureMode'. The *class* 'PotentialEffectofDesignFailureMode' is associated with *data properties* 'SeverityRating' and 'Classification' to provide insight into the significance of the failure mode. This understanding is crucial in determining the amount of mitigation required to address the failure mode, i.e., a failure of high severity is generally given more attention than one with lower severity. Within the

'PotentialCauseofDesignFailureMode' *class*, we have connections to both prevention and detection controls, as well as Risk Priority Number (RPN) Value and 'OccurrenceRating'. By connecting these *classes* and *properties*, we are able to provide an explicit linkage and a more complete view of the design knowledge related to the design item. Additionally, these connections are vital to enhancing the knowledge base of the design force, thereby helping to improve the quality and reliability of the product. As Cassanelli et al. (2006) indicate, a good FMEA improves reliability by introducing proper corrective actions that lower failure rates. Graphically, the design branch of the ontology is shown in Figure 10 below.

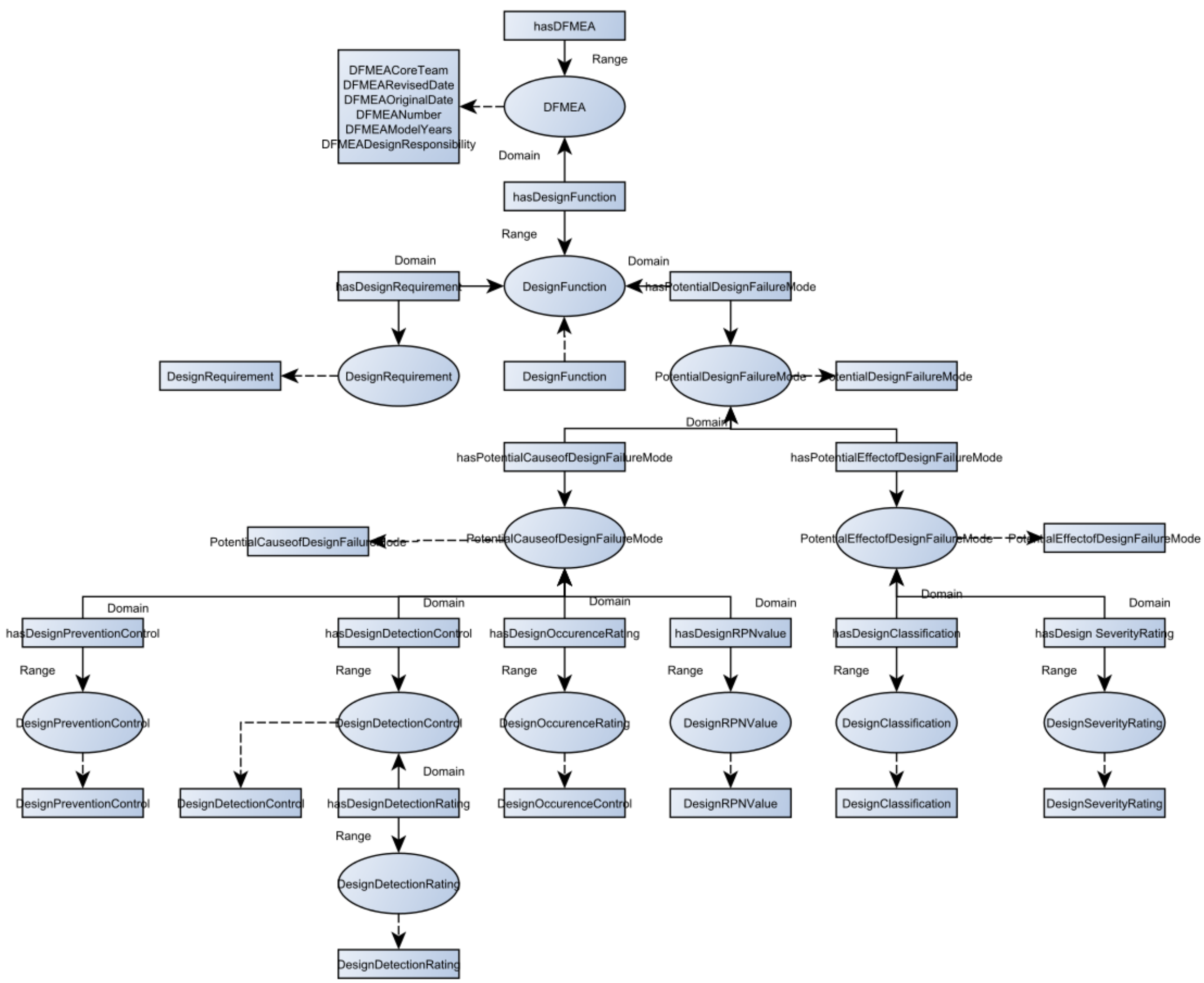


Figure 10: Design and process manufacturing ontology development: Design branch

Ontology Development - Process Concepts Branch

This branch describes the relationships pertaining to the design item's associated process knowledge. Here, the connections stem from the *class* 'operation', which define the activities associated to the manufacturing process. The *class* 'operation' is the central terminal upon which the concepts from the Process Flow, PFMEA and Control Plan are routed. This is a logical designation in that the individuals within the *class* 'operation' comprise the manufacturing process and hence are the hub for further analysis. From here, similarly to the DFMEA, potential failure modes and their respective ratings and controls are relationally linked. Additionally, concepts from the control plan, i.e. those value-added actions required to assure that all process outputs are in state of control (AIAG, 2008a), are also connected to the entities from *class* 'operation'. These connections can be seen in Figure 11 below.

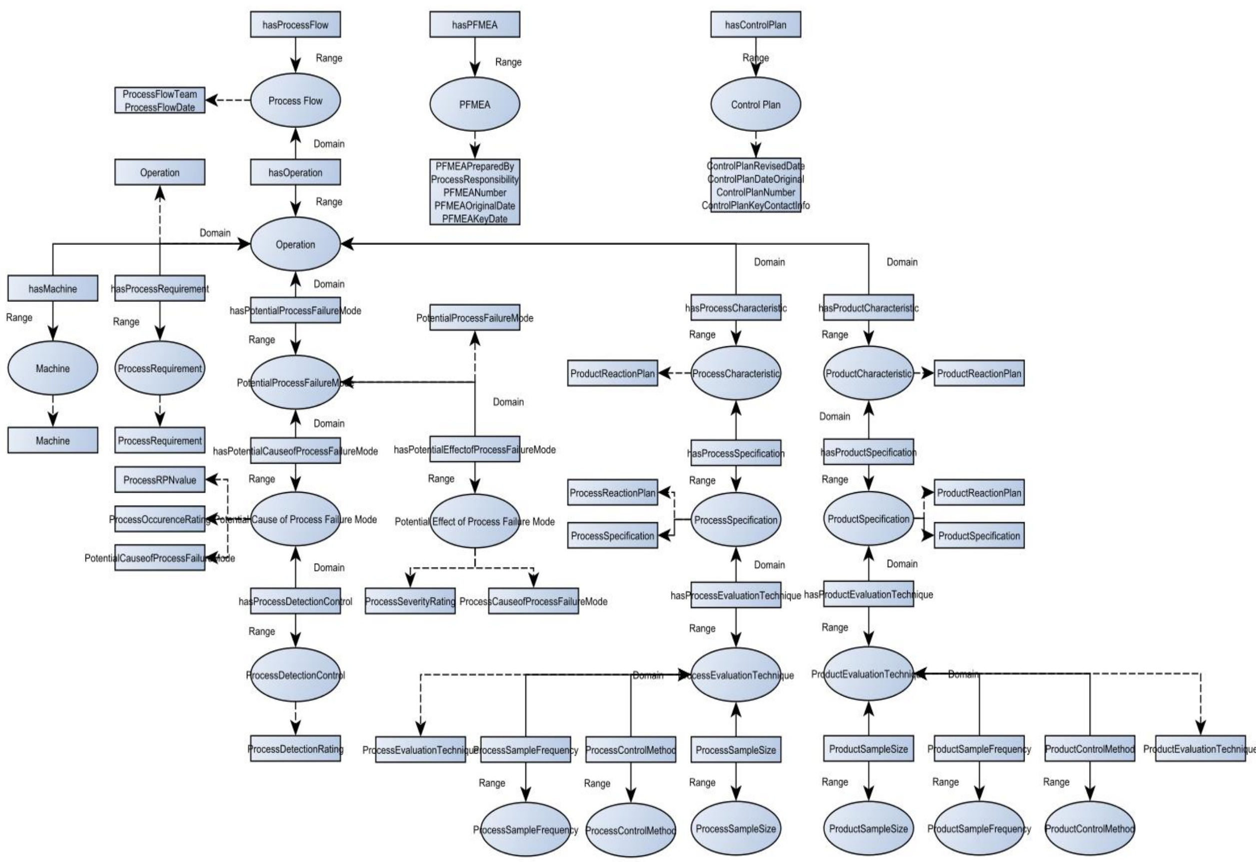


Figure 11: Design and manufacturing ontology development: Process branch

Finally, by linking the design functions and process operations to the design item, this allows a broad and interconnected framework explicitly associating both design and process knowledge. Figure 12 shows the complete DPFO. Given the general nature of the concept mappings, the ontology can be reasonably applied to any design and manufacturing product.

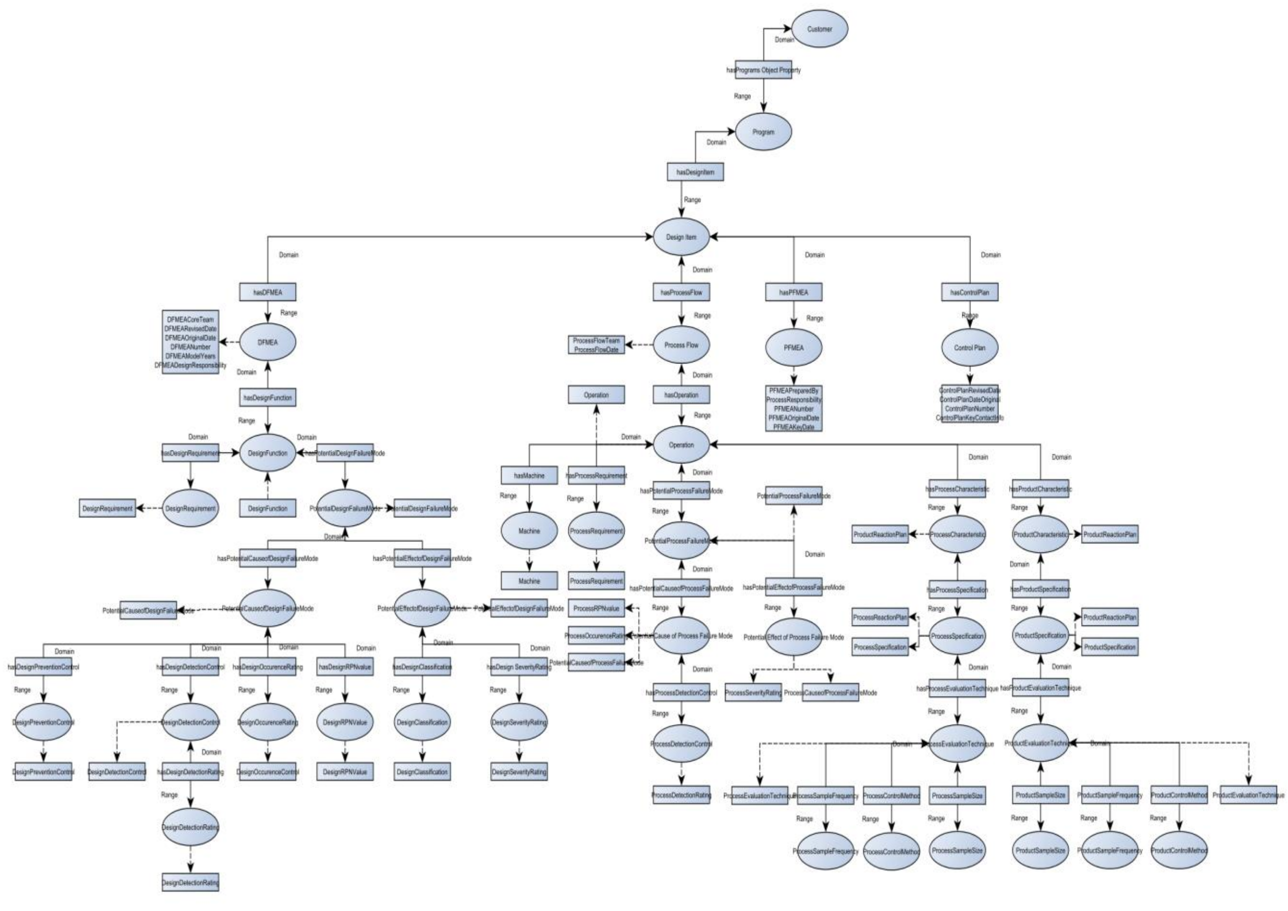


Figure 12: Full Design and Process Functional Ontology (DPFO)

Ontology Formalization

To formalize the ontology, the ontology editor tool Protege was used. Protege is a graphical tool for ontology construction (Stanford Center for Biomedical Research, 2015). Although the tool was developed at Stanford Medical Informatics and it has been historically driven by biomedical applications (Gennari, et al., 2003), the system is domain-independent and has been successfully applied to many other industries as well. The sequence of steps used was as follows: 1) Create classes, 2) Create properties (Object properties and Data properties), 3) Add individuals & assign properties, and 4) Run Reasoner and validate subsumption testing.

Although not mandatory, and consequently not listed as a formal step in developing the ontology, an International Resource Identifier (IRI) was specified to define the ontology (W3Cb, 2015). In this case, the selected IRI reflects the ontology's web location, i.e. 'http://www.peterchhim.site88.net/Dissertation-ontology.owl'. Next, the ontology's concepts were defined as *classes*. Note: All *classes* are of subclass 'Thing', and are disjointed to prevent an individual from being an instance of more than one class (Horridge, Knublauch, Rector, Stevens, & Wroe, 2004). Essentially, this is done to avoid multiple inheritance and to support logical inferences. For example, it would be illogical if an individual from class 'Person' was also assigned to class 'Car', i.e. how could a 'Person', also be a 'Car'? Hence, to avoid such cases, *classes* are disjointed.

Next, the *object properties* connecting the individuals between *classes* were defined. To denote ownership between the domain and range between *classes*, a convention of starting each *object property* with 'has' was employed, e.g., the *object property* connecting *class* 'DesignItem' with *class* 'DFMEA' was named, 'hasDFMEA'. Next, the *data properties* for the individuals were defined. Here, given the range for the *data property* is a value, and not a class, the 'has' convention for the object properties was not employed. Instead, simply the name of data property was used, e.g. the *data property* for identifying the part number for *class* 'DesignItem' was named, 'Partnumber'. Next, the individuals for each *class* were defined. To assist with clear delineation between 'DesignItem' individuals, the type of design item and a sequential entry number were used as prefixes. For example, to identify the first entry of a design item called 'End Support', and its corresponding Control Plan, the following convention was employed: 'EndSupport1ControlPlan'. This type of naming convention helps to clearly distinguish the intent and class association of the individual being defined. Next, each individual was assigned their respective class type, object and data property (as applicable). Finally, once all the individuals had been defined, Protege's *reasoner* tool was employed. The *reasoner* is a tool that is used to test whether or not one class is a subclass of another class, a process known as subsumption testing (Horridge, Knublauch, Rector, Stevens, & Wroe, 2004). Protege version 4.3.0 has two reasoner options, FaCT++, and HermiT 1.3.8. FaCT++ is a Description Logics (DLs) reasoner designed with tableaux algorithms and optimization techniques (Tsarkov & Horrocks, 2006), while HermiT is a more recent DL reasoner that employs 'hyper-tableau' calculus to address problems due to nondeterminism and model size (Shearer, Motik, & Horrocks, 2008). The ontology was run through both reasoners and no errors emerged.

Publication of the Ontology

Publishing the ontology is the process of making the ontology available on the web. The obvious benefit in doing so is that once complete, the ontology can be accessed anywhere an internet connection is available. Additionally, SPARQL allows for querying of multiple ontologies. Thus, by making them available online it increases the scope and the utility of the data. In this case, after the ontology was formalized via protégé, it was then uploaded onto the web via a simple freeware file serving client. In Figure 13, a screenshot of the uploaded ontology is shown.

```
peterchhim.site88.net/Design%20and%20manufacturing%20ontology,%20revised%2007-14-15.owl

<?xml version="1.0"?>


<!DOCTYPE rdf:RDF [
    <!ENTITY owl "http://www.w3.org/2002/07/owl#" >
    <!ENTITY xsd "http://www.w3.org/2001/XMLSchema#" >
    <!ENTITY rdfs "http://www.w3.org/2000/01/rdf-schema#" >
    <!ENTITY rdf "http://www.w3.org/1999/02/22-rdf-syntax-ns#" >
    <!ENTITY untitled-ontology-31 "http://www.semanticweb.org/pchhim/ontologies/2014/1/untitled-ontology-31#" >
    <!ENTITY _ "http://www.semanticweb.org/pchhim/ontologies/2014/1/untitled-ontology-31#hasModel_Year(s)_/" >
]>


<rdf:RDF xmlns="http://www.w3.org/2002/07/owl#"
     xml:base="http://www.w3.org/2002/07/owl"
     xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
     xmlns:owl="http://www.w3.org/2002/07/owl#"
     xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
     xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
     xmlns:_="&untitled-ontology-31;hasModel_Year(s)_/"
     xmlns:untitled-ontology-31="http://www.semanticweb.org/pchhim/ontologies/2014/1/untitled-ontology-31#">
    <Ontology rdf:about="http://peterchhim.site88.net/Design%20and%20manufacturing%20ontology,%20revised%2012-13-14.owl">
        <versionIRI rdf:resource="http://peterchhim.site88.net/Design%20and%20manufacturing%20ontology,%20revised%2012-13-14.owl"/>
    </Ontology>



    <!--
    ///////////////////////////////////////////////////////////////////////////////////////
    //
    // Object Properties
    //
    ///////////////////////////////////////////////////////////////////////////////////////
     -->




    <!-- http://www.semanticweb.org/pchhim/ontologies/2014/1/untitled-ontology-31#hasControlMethod -->

    <ObjectProperty rdf:about="&untitled-ontology-31;hasControlMethod">
        <rdfs:range rdf:resource="&untitled-ontology-31;ControlMethod"/>
        <rdfs:domain rdf:resource="&untitled-ontology-31;Evaluation/MeasurementTechnique"/>
        <rdfs:subPropertyOf rdf:resource="&untitled-ontology-31;hasEvaluationTechnique"/>
    </ObjectProperty>



    <!-- http://www.semanticweb.org/pchhim/ontologies/2014/1/untitled-ontology-31#hasControlPlan -->

    <ObjectProperty rdf:about="&untitled-ontology-31;hasControlPlan">
        <rdfs:range rdf:resource="&untitled-ontology-31;ControlPlan"/>
```

Figure 13: Published ontology

Querying and Utilization of the Ontology

Querying the ontology is made possible through another Semantic Web tool called a SPARQL endpoint. A SPARQL endpoint is simply a processor that accepts SPARQL queries (Ducharme, 2013). The SPARQL endpoint we employed was a part of the Protégé package. To test the utility of the ontology, several queries were run. In particular, Figure 14 shows a complex SPARQL query that is interpreted as follows:

‘For the ontology’s design item and part number, provide all the potential causes of design failure modes and rank order them by their Risk Prevention Number or RPN Value. Additionally,

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX my: <http://www.semanticweb.org/pchhim/ontologies/2014/1/untitled-ontology-31#>
SELECT DISTINCT ?ind ?DesignPartNumber ?PotentialCauseOfDesignFailureMode
?DesignRPNValue ?DesignPreventionControl ?DesignDetectionControl
WHERE
{
    {?ind rdf:type ?DesignItem .
    ?ind my:DesignPartNumber ?DesignPartNumber .}
    UNION
    {?ind rdf:type ?PotentialDesignFailureMode .
    ?ind my:PotentialCauseOfDesignFailureMode ?PotentialCauseOfDesignFailureMode .
    ?ind rdf:type ?PotentialCauseofDesignFailureMode .
    ?ind my:DesignRPNValue ?DesignRPNValue .}
    UNION
    {?ind rdf:type ?PotentialCauseofDesignFailureMode .
    ?ind my:DesignPreventionControl ?DesignPreventionControl .}
    UNION
    {?ind rdf:type ?PotentialCauseofDesignFailureMode .
    ?ind my:DesignDetectionControl ?DesignDetectionControl .}
}

ORDER BY DESC (?DesignRPNValue)
```

Figure 14: SPARQL query

Next, we will cover the various sections of the query in detail. To begin, we will review the PREFIX and SELECT features.

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

PREFIX owl: <http://www.w3.org/2002/07/owl#>

PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>

PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>

```
PREFIX my: <http://www.semanticweb.org/pchhim/ontologies/2014/1/untitled-ontology-31#>
SELECT
DISTINCT ?ind ?DesignPartNumber ?PotentialCauseOfDesignFailureMode ?DesignRPNValue ?DesignPreve
ntionControl ?DesignDetectionControl
```

We begin by defining PREFIXs associated to standard schema. These include rdf, owl, xsd, and rdfs. Next, we add the IRI for our ontology by defining the PREFIX: ‘my: http://www.semanticweb.org/pchhim/ontologies/2014/1/untitled-ontology-31#’. This ability to identify ontologies is one of the significant advantages RDF and SPARQL have over relational databases and allows for federated queries across ontologies (Martinz-Cruz et al., 2012). The SELECT feature then allows us to identify the variables of interest, i.e. the individuals associated to the Design Part Number, Potential Causes of the Design Failure Mode, Design RPN Value, Design Prevention and Design Detection Control. Additionally, we apply the DISTINCT feature to eliminate duplicates in our resulting output.

Next, the WHERE feature is used to identify the location within the ontology where our variables of interest are located. In our first triple set, the use of RDF schema ‘type’, allows us to associate our subject, ‘ind’ (simply a variable placeholder), with the object of ‘DesignItem’, that is, it is identifying individuals of type DesignItem. We connect this with a subsequent triple that asks for those individuals with an object property called ‘DesignPartNumber’, and object called ?DesignPartNumber. Hence, this triple set allows us to identify the individual DesignItems within the ontology that have a DesignPartNumber, and display the DesignPartNumber.

```
WHERE
    {
    {?ind rdf:type ?DesignItem .
    ?ind my:DesignPartNumber ?DesignPartNumber .}
```

Following this, we use the UNION feature to extend our query by identifying different graph patterns that the processor can use to fit and combine results. This is an important feature in that without it, complex SPARQL queries may not return results if the specified graph pattern does not match the triples presented within it (Ducharme, 2013). Using the UNION feature allows us to avoid this issue, by telling the processor to pull overlapping sets of data without needing a connection between them.

Here, we again ask for individuals of type PotentialDesignFailureMode, but this time only those that have an object property called PotentialCauseOfDesignFailureMode. Additionally, we also ask the processor to provide the DesignRPNValue associated to these object properties given we know (as defined by our ontology) each Potential Cause of Design Failure Mode has an RPN Value associated to it.

```
UNION
    {?ind rdf:type ?PotentialDesignFailureMode .
    ?ind my:PotentialCauseOfDesignFailureMode ?PotentialCauseOfDesignFailureMode .
    ?ind rdf:type ?PotentialCauseofDesignFailureMode .
    ?ind my:DesignRPNValue ?DesignRPNValue .}
```

Thirdly, we again use the UNION feature to identify both the Design Prevention and Detection Controls associated to the Potential Cause of Design Failure Mode.

```
UNION
    {?ind rdf:type ?PotentialCauseofDesignFailureMode .
    ?ind my:DesignPreventionControl ?DesignPreventionControl .}
    UNION
    {?ind rdf:type ?PotentialCauseofDesignFailureMode .
    ?ind my:DesignDetectionControl ?DesignDetectionControl .}}
```

Lastly, we use the ORDER BY DESC feature to rank order the Design RPN Values by descending order. Since the DesignRPNValue is connected to the Potential Cause of Design Failure Mode in our first triple set, it rank orders the objects within this triple as well. This is a useful feature, in particular within the context of manufacturing continual improvement in that it quickly identifies which potential failure mode has the greatest risk as defined by the RPNValue.

```
ORDER BY DESC (?DesignRPNValue)
```

After we run our query, we see that the resulting output demonstrates the ability of SPARQL to accurately identify the specific subset of data, rank order the variable of interest and provide the full results. This query ability is a significant enhancement over traditional keyword based searches in that it does not muddy the search results by simply providing a text field match; instead, it is targeting a specific area of the data to provide a more precious and richer response. Additionally, the simplicity of triple matching and federated query is an enhancement over traditional relational databases. Revisiting our earlier APQP issue, instead of having to scroll through multiple documents/files and apply various keyword searches to find specific information of interest, using this ontological approach allows a user to more rapidly and precisely locate this information. Figure 15 below shows the output of our SPARQL query (note: in order to capture the full results, Figure 15 combines sectioned images of the resulting SPARQL output).

ind	DesignPartNumber	PotentialCauseOfDesignFailureMode	DesignRPNValue
Side_Rail_1_Design_Function_2_Potential_Cause_of_Desi		"Material twist variability not accounted for."^^<http://www.w3.org/2001/XMLSchema#string>	"80"^^<http://www.w3.org/2001/XMLSchema#int
Side_Rail_1_Design_Function_5_Potential_Cause_of_Desi		"Presence of stress risers in design."^^<http://www.w3.org/2001/XMLSchema#string>	"80"^^<http://www.w3.org/2001/XMLSchema#int
Side_Rail_1_Design_Function_5_Potential_Cause_of_Desi		"Material classification/ thickness/geometry incorrect for application."^^<http://www.w3.org/2001/XMLS	"80"^^<http://www.w3.org/2001/XMLSchema#int
Side_Rail_1_Design_Function_1_Potential_Cause_of_Desi		"Part Twist "^^<http://www.w3.org/2001/XMLSchema#string>	"64"^^<http://www.w3.org/2001/XMLSchema#int
Side_Rail_1_Design_Function_3_Potential_Cause_of_Desi		"Incorrect center support orientation. "^^<http://www.w3.org/2001/XMLSchema#string>	"60"^^<http://www.w3.org/2001/XMLSchema#int
Side_Rail_1_Design_Function_3_Potential_Cause_of_Desi		"Sweep or crown of of rail misaligns lock and load feature. "^^<http://www.w3.org/2001/XMLSchema#s	"60"^^<http://www.w3.org/2001/XMLSchema#int
Side_Rail_1_Design_Function_8_Potential_Cause_of_Desi		"Incorrectly designed trailing edge profiles."^^<http://www.w3.org/2001/XMLSchema#string>	"40"^^<http://www.w3.org/2001/XMLSchema#int
Side_Rail_1_Design_Function_2_Potential_Cause_of_Desi		"Slot width or height designed too narrow, crossbar binds in side rail channel. "^^<http://www.w3.org/:	"40"^^<http://www.w3.org/2001/XMLSchema#int
Side_Rail_1_Design_Function_7_Potential_Cause_of_Desi		"Variability in appearance sprectrum between components. "^^<http://www.w3.org/2001/XMLSchema#	"35"^^<http://www.w3.org/2001/XMLSchema#int
Side_Rail_1_Design_Function_7_Potential_Cause_of_Desi		"Incorrect material specified. "^^<http://www.w3.org/2001/XMLSchema#string>	"30"^^<http://www.w3.org/2001/XMLSchema#int
Side_Rail_1_Design_Function_7_Potential_Cause_of_Desi		"Cleaning product interaction"^^<http://www.w3.org/2001/XMLSchema#string>	"30"^^<http://www.w3.org/2001/XMLSchema#int
Side_Rail_1_Design_Function_6_Potential_Cause_of_Desi		"Insufficient coverage/ hider lips on part."^^<http://www.w3.org/2001/XMLSchema#string>	"20"^^<http://www.w3.org/2001/XMLSchema#int
Side_Rail_1_Design_Function_6_Potential_Cause_of_Desi		"Roof/rail (fastener) joint design not allowing full thread engagement - attachment boss causes screws t	"20"^^<http://www.w3.org/2001/XMLSchema#int
Side_Rail_1_Design_Function_2_Potential_Cause_of_Desi		"Inncorrect side rail crown / profile specified. "^^<http://www.w3.org/2001/XMLSchema#string>	"16"^^<http://www.w3.org/2001/XMLSchema#int
Side_Rail_1	"23034"^^<http://www.w3		

ind	DesignPreventionControl
Side_Rail_1_Design_Function_7_Prevention_Control_2	"Material selection guidline based on wear life requirement of product. "^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_7_Prevention_Control_3	"Material selection guidline based on color harmony of components. "^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_5_Prevention_Control_2	"Design rail to withstand 1.5X max load requirement @ front, middle, and rear sections of rail assembly. "^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_8_Prevention_Control_2	"Surrogate part designs."^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_5_Prevention_Control_1	"Design rail to withstand 1.5X max load requirement. "^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_4_Prevention_Control_1	"Follow design guideline for support to side rail attachment. "^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_5_Prevention_Control_4	"Finite Element Analysis (FEA) was conducted to verify the adequate thickness/structure was applied."^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_6_Prevention_Control_2	"Fit function section review at each mating component and attachment location. Root Sum Squared (RSS) tolerance analysis conducted between mating components"^^<http://wv
Side_Rail_1_Design_Function_3_Prevention_Control_1	"Root Sum Squared (RSS) tolerance analysis conducted between mating components to assure failures are detected prior to design release."^^<http://www.w3.org/2001/XMLSch
Side_Rail_1_Design_Function_3_Prevention_Control_2	"Root Sum Squared (RSS) tolerance analysis conducted between mating components to assure failures are detected prior to design release. Center locator tab was added to aid a
Side_Rail_1_Design_Function_7_Prevention_Control_1	"Material selection guidline based on wear life requirement of product. "^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_5_Prevention_Control_3	"Finite Element Analysis (FEA) was conducted to verify the adequate thickness and geometry was applied."^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_2_Prevention_Control_1	"Root Sum Squared (RSS) tolerance analysis conducted between mating components to assure failures are detected prior to design release."^^<http://www.w3.org/2001/XMLSch
Side_Rail_1_Design_Function_1_Prevention_Control_1	"Root Sum Squared (RSS) tolerance analysis between crossbar and side rail to ensure twist allowance is considered and adequate."^^<http://www.w3.org/2001/XMLSchema#str
Side_Rail_1_Design_Function_4_Prevention_Control_2	"Root Sum Squared (RSS) tolerance analysis conducted between mating components to assure failures are detected prior to design release."^^<http://www.w3.org/2001/XMLSch
Side_Rail_1_Design_Function_2_Prevention_Control_3	"Root Sum Squared (RSS) tolerance analysis conducted between mating components to assure failures are detected prior to design release."^^<http://www.w3.org/2001/XMLSch
Side_Rail_1_Design_Function_8_Prevention_Control_1	"Surrogate part designs "^^<http://www.w3.org/2001/XMLSchema#string>

ind	DesignDetectionControl
Side_Rail_1_Design_Function_3_Detection_Control_1	"Ergonomic testing of functional features (OR-0013; OR-0306; RG-0009)."^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_6_Detection_Control_2	"Design studio review per SDS ID 17-0038. Fit function section review at each mating component and attachment location. "^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_7_Detection_Control_1	"Appearance testing to OR-0009; 17-0005; MA-0124, 0128, 0130, 0131, PA-0042, 0045, 0148; RG-0003. "^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_2_Detection_Control_2	"Ergonomic testing of functional features (OR-0013; OR-0306; RG-0009)."^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_2_Detection_Control_3	"Ergonomic testing of functional features (OR-0013; OR-0306; RG-0009)."^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_6_Detection_Control_1	"Design studio review per SDS ID 17-0038. Fit function section review at each mating component and attachment location. "^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_8_Detection_Control_1	"Wind tunnel testing to (OR-0011)."^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_7_Detection_Control_3	"Appearance testing to OR-0009; 17-0005; MA-0124, 0128, 0130, 0131, PA-0042, 0045, 0148; RG-0003. "^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_4_Detection_Control_2	"Load testing 200 lbs; Loading and configurations in accordance with SDS (OR-0014; OR-0037; OR-0306; OR-0319; OR-0322, 0323, 0324)"^^<http://www.w3.org/2001/XMLSche
Side_Rail_1_Design_Function_2_Detection_Control_1	"Ergonomic testing of functional features (OR-0013; OR-0306; RG-0009)."^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_7_Detection_Control_2	"Appearance testing to OR-0009; 17-0005; MA-0124, 0128, 0130, 0131, PA-0042, 0045, 0148; RG-0003. "^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_4_Detection_Control_1	"Load testing 200 lbs; Loading and configurations in accordance with SDS (OR-0014; OR-0037; OR-0306; OR-0319; OR-0322, 0323, 0324)"^^<http://www.w3.org/2001/XMLSche
Side_Rail_1_Design_Function_1_Detection_Control_1	"Crossbar load testing OR-0014; OR-0037; OR-306; OR-0319; OR-0322, 0323, 0324."^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_3_Detection_Control_2	"Ergonomic testing of functional features (OR-0013; OR-0306; RG-0009)."^^<http://www.w3.org/2001/XMLSchema#string>
Side_Rail_1_Design_Function_5_Detection_Control_1	"Add load limit to vehical owners manual. Load testing 200 lbs. Loading and configurations in accordance with SDS (OR-0014; OR-0037; OR-0306; OR-0319; OR-0322, 0323, 0324)
Side_Rail_1_Design_Function_5_Detection_Control_2	"Add load placement guidelines to vehical owners manual. Load testing 200 lbs. Loading and configurations in accordance with SDS (OR-0014; OR-0037; OR-0306; OR-0319; OR-0
Side_Rail_1_Design_Function_5_Detection_Control_4	"Load testing 200 lbs. Loading and configurations in accordance with SDS (OR-0014; OR-0037; OR-0306; OR-0319; OR-0322, 0323, 0324)"^^<http://www.w3.org/2001/XMLSchei

Figure 15: SPARQL output result

Conclusions

As competition in the manufacturing sector continues to increase, knowledge management maintains an important role. For those organizations that rely on EKRs for the purposes of knowledge reuse, turning to ontologies and the Semantic Web is a potent option to gain greater advantage. By encoding design and process knowledge into ontologies, organizations are able to capture, share and accurately query these knowledge bases to gain recall with few geographical limitations. Through our research, we present DPFO, a thorough and significantly enhanced ontology from existing offerings within the literature. This broader effort connects design and process knowledge to help close a research gap while simultaneously addressing a problem of practice. Additionally, to increase the applicability of the ontology, the concepts within it are generalized such that it can be applied across the design and manufacturing domain.

The functionality and utility of the ontology is demonstrated through the use of Apache Jena's Fuseki server and a SPARQL end point query. The results of the query demonstrate the validity of the effort as the SPARQL query is able to accurately retrieve the requested information. Instead of simple keyword based searches that provide muddled and excessive results because of semantic inconsistencies and syntactic errors, the use of RDF data and SPARQL queries provides considerably more accurate and richer results. Additionally, to address the lack of wide spread usage of ontologies, we provide a simple yet constructive and systematic methodology for ontology development. Instructively, our research turned to the industry famous six sigma framework and its wide spread adoption, to inform a method that was diametrically opposite to 'of the academia, by the academia, and for the academia' approach (Goh, 2010). The logic being, given the emphasis is on enhancing industry based ontology usage, the approach needed to be delivered in a manner that encouraged practitioner rather than academic adoption. Hence, while our methodology is comprehensive, it is presented in a step-by-step manner that detail the full ontology cycle from conceptualization to realization.

CHAPTER 4: CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

As we continue our march through the information age, research efforts that are aligned with industry movement are key in both illuminating the path forward, as well as mapping our existing position to help us gain a better understanding of where we are and how we got there. In the case of KM, the growing industrial movement towards its adoption cannot be understated. With its recent inclusion into the ISO 9001 standard, a potential swath of over a million companies will be affected. This significant moment in time brings with it not only fear and trepidation from those who will no doubt struggle with how to operationalize KM, but also a grand opportunity for research to make a substantial impact into everyday life. Consequently, this research along with those similar others reflecting the increased academic attention in KM, and in particular KMS and EKRs, aim to take advantage of this fertile opportunity. In doing so, first I summarize the major findings from both research focuses, present limitations and directions for future research, and then in the spirit of the program in which this dissertation is presented, I reflect upon best practices in KM to provide more holistic guidance to inform corporate management. We begin by reviewing the first research focus and our multi-theoretical approach to KRU via EKRs.

KRU via EKRS

In the case of EKRs, a multi – theoretical and sequentially logical model for KRU is developed and tested. The front end of the model is comprised of those IT and Organizational factors that predict KRU and is informed via the Socio-Technical theory. Using this perspective, I' am able to find support within the context of EKRs that a healthy union of socio and technical factors is required for success. This finding should not go overlooked in that IT in and of itself cannot produce the results needed for organizations to maximize their intellectual capital. Instead, the union of socio and technical elements helps to realize this potential by adding a 'sense making' and human element to the knowledge within the technical architecture. Next, the use of the ECM perspective to model the back end, resulting outcome view of KRU provides a useful framework to study CON through an application's outcome measure of interest. Moreover, it helps to validate the importance of EKRs in that the predictive relationship between KRU and PER is the highest in the model. Additionally, the benefits from greater KRU extend beyond performance and into the realm of KS and CON. This is important to note in that KRU is not limited to an immediate outcome, but rather reflects a reinforcing cycle that fosters not only greater KS, but also greater CON. Capping this research piece and providing a lead in to the second research solution is the strong tie between EUCS and KRU, i.e. the research found that greater EUCS predicts greater KRU. Hence, it is logically sound to posit that by enhancing EUCS, e.g. by improving the internal composition of the EKR through the use of an ontology that relationally maps knowledge within a domain, a larger impact to KRU can be expected. Thus, for those organizations that rely on EKRs for the purposes of knowledge reuse, turning to ontologies and the Semantic Web is a potentially potent option for greater KRU and EKR usage. However, before advancing to that particular topic, we conclude this section with a review of research limitations and recommendations for future research.

There are several methodological limitations in this study. First, the data collected is self-reported. Consequently, this may result in measuring an impression of intent rather than actual occurrence. Additionally, while the demographics for the survey cover a broad range of industries, the number of respondents representing each industry can be considered low, for example, seven industries had less than 10 respondents in their grouping. Given this limited representation, there is a possibility that a larger sampling within a particular industry could lead to more industry specific attitudes and results. Thus, future research can narrow its focus towards industry specific sectors to determine if prevalent attitudes within them become manifested via alternate results and findings. For example, KVP may be of greater importance in fields such as the technical support industry where solutions are less ambiguous. As well, the location of respondents was not captured, and hence there is a potential for a similar type of location specific predisposition given a larger and more localized sampling were to occur within a specific region. This narrowed focus may also lend itself to greater statistical validation, i.e., a larger and more heterogeneous sampling could yield more statistical power and allow for more rigorous model testing.

Next, for those questions within the survey that required a respondent to narrow their focus on a single EKR when responding, there is a potential that this fixation could have skewed responses to those that are more temporally recent, and valence positive. As explained by D'Argembeau and Van der Linden (2004), there is a tendency to recall positive experiences and recent events with greater clarity that can consequently influence a user's response. Further, the data is cross-sectional and consequently represents a single point in time, thus, the research does not evaluate improvements made to the exogenous variables that could potentially influence their impact on their respective dependent variables. This is especially relevant in the case of EUCS where technological advancements can occur rapidly, and consequently impact the construct and thus its relationship with KRU through EKRs. Moreover, given the importance of sustainability and continued EKR usage, future studies can focus on those dimensions that may result in greater usage, particularly via the effect of technological change. Hence, a follow-up longitudinal study could be employed to re-assess the model and the strength of its relationships. Next, there is no doubt that within industry there are varying types of knowledge repositories. These differences could play a role in the strength of the model's relationships. Hence, a direction for future research could be in studying the various types of repositories found in industry and identifying those components within them that play a significant role in KRU. Finally, and as previously mentioned, our PLS-SEM approach is a first attempt at modeling a comprehensive view of KRU via EKR. Although our findings have helped to shape our interpretation of this area, the next logical step would be to refine the model and conduct CB-SEM for theory confirmation and assessment of causal linkage between the factors. Next we turn to the second research focus, i.e. the ontological improvement effort of manufacturing EKRs.

Enhancing Manufacturing EKRs via Ontologies and Semantic Web Tools

The research presents DPFO, a thorough ontological offering that extends existing efforts from the literature. While previous contributions either fall into broad manufacturing, or narrow design or failure mode approaches, this research is the first to intimately connect design and process knowledge via their requirements, functions, and associated failure modes and controls. For instance, design requirements, design functions, design failure modes, severity rankings, and both detection and prevention controls are all interconnected within the domain, but also link to the processes corresponding operations, requirements, failure modes, controls, and the like. This presents a level of design and process connection that is extremely suited to knowledge reuse. For instance, if a new designer wanted to plan for similar failure modes from a previously launched product, a simple query could provide this information succinctly without polluting the results with erroneous details and ultimately limiting reuse. To demonstrate the functionality and utility of the ontology, a complex query is offered which yields rich and accurate details of the data within the ontology. This information retrieval is a significant enhancement to the simple keyword based approach in that it not only provides accurate results, but it does so without muddying the results with irrelevant and convoluted returns. Additionally, through the use of federated queries, the ontological approach extends beyond traditional relational databases in that it is able to more effectively query multiple and remote data sources. Furthermore, the research also offers a constructive, yet simple and systematic approach to ontology development to help address the lack of wide spread usage ontology usage.

In terms of future research efforts, the challenge of mainstreaming a tool such as ontologies and the use of Semantic Web technologies is still quite formidable. While we have provided a clear step-by-step approach to ontology development and realization, there are still quite formidable challenges from both a front and backend perspective. From the front end although users knowledgeable of SPARQL can develop and utilize queries to draw accurate and rich information from the ontology, this level of knowledge is esoteric and hence not useful for mass consumption. Consequently, additional efforts can focus on developing user-friendly interfaces that mask the SPARQL programming requirement, thereby allowing users access to improved queries without having to be fluent in the programming language to do so. From a back end perspective, the challenge of converting existing EKR knowledge into an ontological framework can be a considerable endeavor, especially for those mature repositories that contains hundreds of thousands, if not more, entries. Given the existing ontology development and formalization steps are typically manual, mapping tools that can help streamline and automate the conversion process are needed for transitioning existing EKR knowledge into corresponding ontologies. The identification of a viable approach to complete such a task would not only help to fill a sizeable research gap, but would also address a significant problem of a practice. Finally, while we provide theoretical evidence to support the use of ontologies to structurally map the contents of manufacturing EKRs and thereby improve EUCS through enhanced query accuracy and recall, there has yet to be an empirical effort validating this theory. In particular, future research can look to quantitatively assess the impact that ontologies play on manufacturing EKRs and thus quantify the resulting affect they have on KRU and EKR usage.

Broader KM Recommendations for Organizational Leadership

As previously mentioned, in the spirit of the program in which this dissertation is presented, it would be remiss to complete this dissertation without providing pragmatic, broader KM recommendations to inform organizational management. The GET program truly is a mechanism for creating a new class of technical leaders with the ability to create sustainable value (Wayne State University, 2015) wherever their efforts take them. Within this vein, I meld the recommendations between those found in the popular press and industrial specific literature with the findings from this research to offer a balanced set of recommendations for organizational management to consider.

To begin, and in conjunction with our research finding connecting KMST and KRU, we turn to Hansen et al. (1999) and their pragmatic and fundamental query concerning all KM motivated organizations, i.e. 'What's your strategy for managing knowledge?' This basic question forces organizations to reflect upon the need of their business and hence the appropriate KM strategy to employ. The two most applied approaches to KM are the system-oriented or codification approach, and the human-oriented or personalization approach (Hansen et al., 1999). The personalization approach focuses on the tacit dimension of knowledge and the interaction and sensemaking of others to communicate and contextualize knowledge. Within this arena, efforts such as communities of practice (Wenger, McDermott, & Snyder, 2002), knowledge cafes (Gurteen, 2015), networks of experts and electronic discussion forums (Hanh & Subramani, 2000) are commonly found. The codification approach to KM assumes knowledge can be made explicit and relies on KMS to help extract, store, package and make available knowledge for others to reuse

(Hanh & Subramani, 2000). Here, tools such as databases, reposoitories, document warehouses and the like can be found.

However, identification of the correct strategy is not always an obvious choice. In the context of a global ogranization, managing knowledge in a global arena is much different, more complex and more complicated than in a local environment (Desouza & Evaristo, 2003). Determining the type of KM strategy required depends on the specific knowledge management problems surrounding the organization. Considerations such as uncertainty, equivocality, ambiguity and complexity need to be considered (Zack, 1999). Ultimately though, the identification of the correct KM strategy for the oganizaton is key to maximizing and realizing the organization's KM potential.

Next, leadership must own and drive the KM intiaitive. Organizational culture springs forth from the beliefs,values, and assumptions of organizational leaders (Schein, 2010), and consequently, the behavior and interests of leaders help shape the importance of the initiative to the rest of the organization. Additionally, leaders are also required to help manage the organizational change and the accompanying anxiety associated with said change. This can be done by creating a 'psychological safety net' (Schein, 2010) that lowers anxiety through involvement, training, communication of a compelling vision, positive feedback (Dijoux, 2015) and the like. Hence, without a strong and enduring drive from leadership, the KM initiative may prove futile. Returning now to the findings from this particular research effort, and its codification centric theme, the remaining recommendations will reflect KMS, and in particular, EKRs.

Leveraging existing technology and the ontology friendly architecture of the Semantic web is a logical evolutionary step in configuring the knowledge within EKRs. The benefits of relational mapping help to bring semantic consistency and the use of semantic tools such as SPARQL and

RDF enhance the ability to accurately retrieve information. Hence, product centric organizations should strongly consider the use of ontologies to frame their organizational knowledge within EKRs. Note though, the task of performing such a feat can be considerable, especially the upfront costs associated to initial ontology development, so organizations need to be committed to the approach and exhibit patience to allow the fruits of the labor to bloom. Finally, from a upfront perspective, the largest predictor of KRU via EKRs was found to be End User Computing Satisfaction (EUCS). The importance of this finding cannot be understated in that if users of the system are unsatisfied, they are less likely to obtain and reuse knoweldge from it. Hence, the business of improving the EKR shouldn't be a one time event, but rather a constant reflective and interactive effort with systems users to identify and realize opportunities for improvement. This social inclusion aligns with our socio-technical perspective which helps supports a healthy and reinforcing union between the two interdependent aspects.

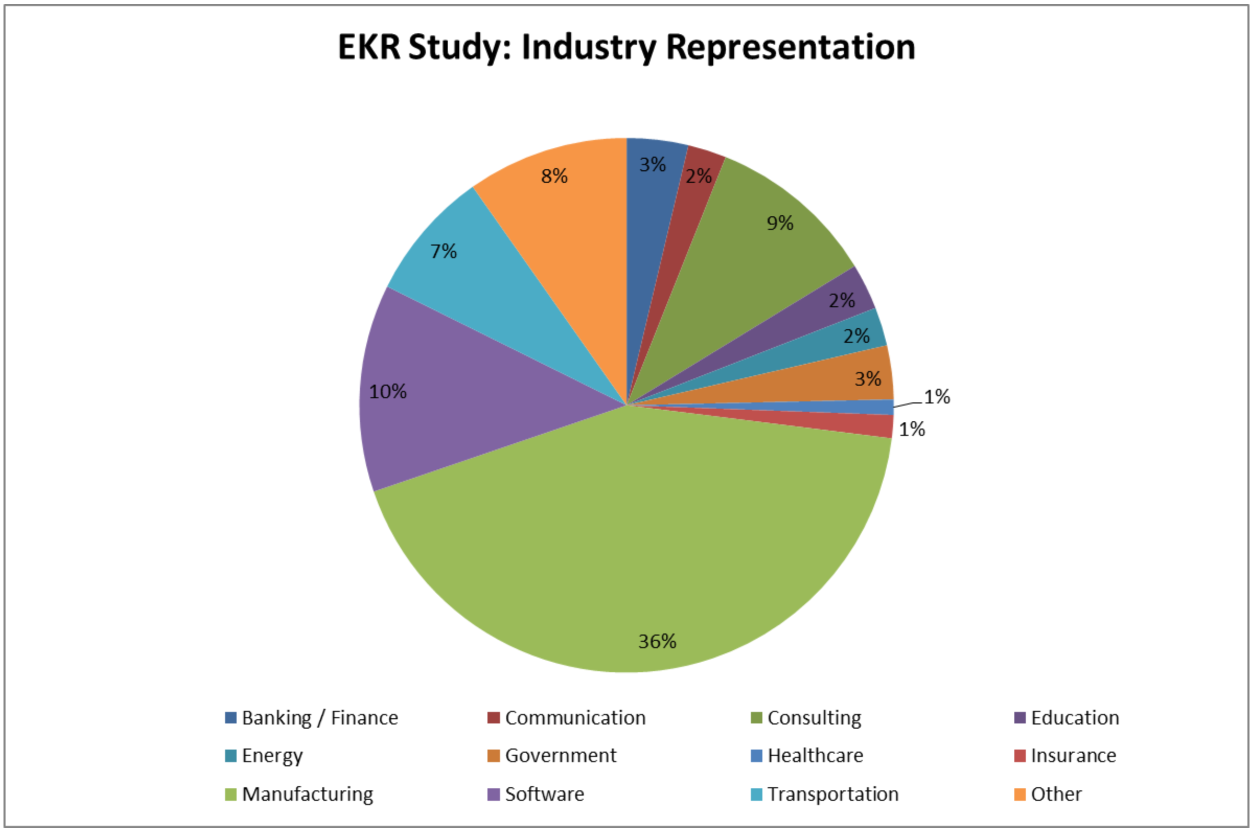
APPENDIX A: OPERATIONALIZATION OF CONSTRUCTS

Construct	Item	Measurement	Source
Worker Interaction and Collaboration (WIC)	To help answer the following questions, consider how the items below apply to your day to day activities at work.		Author
	WIC1	I often work with others.	Adapted from (Walker & Fraser, 2005)
	WIC2	I often relate my work to other's work.	
	WIC3	I discuss my ideas with others within the company.	
	WIC4	Group work is a part of my job responsibilities.	
	WIC5	There is a willingness to collaborate across organizational units.	Adapted from (Lee & Choi, 2003)
Knowledge Management Strategy (KMST)	To help answer the following 7 questions, Intellectual Capital (IC) is defined as the combination of your company's human capital (its people and their skills), organizational capital (patents, systems, policies, procedures), and customer capital (brand, reputation, relationships with customers and suppliers).		IC reference (Stewart & Ruckdeschel, 1988)
	KMST1	We have incorporated strategies regarding IC into strategic thinking and planning.	(Nelson & McCann, 2010)
	KMST2	Our top leadership supports and engages in an active dialogue about knowledge management.	
	KMST3	We have adopted explicit measures for assessing and reporting on various forms of IC.	
	KMST4	We have clearly defined strategies for building IC that have adequate resources and budgets.	
	KMST5	Our organization design is specifically evaluated in terms of how well it supports IC application.	
	KMST6	IC is a competitive asset that the organization actively manages.	
	KMST7	We've developed special roles for helping direct and apply IC ('e.g. knowledge managers').	
Information Technology Support of Knowledge Repository (ITS)	Our company's IT provides support...		Author
	ITS1	Regardless of time and place.	Adapted from (Choi, Lee, & Yoo, 2010)
	ITS2	For searching and accessing necessary information.	
	ITS3	For systemic storing and distributing knowledge.	
Learning Culture (LC)	To help answer the following questions, consider your day to day activities at work and how they apply to the statements below.		Author
	LC1	We are good at learning from both our successes and failures.	Adapted from (Nelson & McCann, 2010)
	LC2	Our culture supports sharing and learning from each other.	

	LC3	We support open, ready access by employees to the knowledge created in the organization.	
	LC4	Our leadership empowers employees to apply their knowledge to innovative ends.	
	LC5	Managers view themselves as active learners and teachers.	
Knowledge Validation Process (KVP)	To help answer the following questions, consider the contribution process for your company's Electronic Knowledge Repository.		Author
	KVP1	The review process for contributions to the EKR occur in a timely manner.	Adapted from (Durcikova & Gray, 2009)
	KVP2	It is easy for me to see the status of my contributions to the EKR.	
	KVP3	My contributions to the EKR often end up being rejected.	
	KVP4	Overall, the contribution review process is clear.	
Knowledge Reuse (KRU)	To help answer the following questions, consider the usefulness of the knowledge items obtained from your company's Electronic Knowledge Repository (EKR). As a reminder, a knowledge item is defined as 'actionable information'.		Author
	KRU1	I am often able to apply the knowledge from the EKR to my work.	Adapted from (Lansdale, 1998)
	KRU2	I reuse knowledge from the EKR to help me reduce the time I spend on addressing issues.	
	KRU3	I reuse knowledge from the EKR to help me prevent issues.	Adapted from (Liao & Chuang, 2004)
	KRU4	I reuse knowledge from the EKR to help me reduce training time for new staff.	
	KRU5	I often reuse knowledge from the EKR.	New Item
Knowledge Sharing (KS)	Employees at our company...		Author
	KS1	Share their work reports and official documents with other team members.	Adapted from (Choi, Lee, & Yoo, 2010)
	KS2	Provide material and methodologies to other team members.	
	KS3	Share their experience or know-how with other team members.	
	KS4	I often share information with other employees within the company.	Adapted from (Walker & Fraser, 2005)
Continuance of Use (CON)	CON1	What is the likelihood that you would continue using the electronic knowledge repository?	Adapted from (Nicolaou & McKnight, 2006)
	CON2	If faced with a similar issue or situation in the future, I would use the electronic knowledge repository again.	
	CON3	I would recommend the use of the electronic knowledge repository to my colleagues at work.	

	CON4	I intend to continue using the electronic knowledge repository as a part of my daily activities.	Adapted from (He & Wei, 2009)
Performance (PER)	Using the electronic knowledge repository...		Author
	PER1	helps me to improve products and/or processes.	New item
	PER2	helps me to provide more relevant knowledge to my customers and/or my managers.	Adapted from (Kankanhalli et al., 2011)
	PER3	allows me to reduce the time I spend on addressing issues.	
	PER4	helps me to prevent issues.	
	PER5	helped prevent me from making the same mistakes others made.	Adapted from (Boh, 2008)
End User Computing Satisfaction (EUCS)	I feel the electronic knowledge repository...		Adapted from (Doll & Torkzadeh, 1998)
	EUCS1	provides the precise information I need.	
	EUCS2	has content that meets my needs.	
	EUCS3	provides sufficient information.	
	EUCS4	is accurate.	
	EUCS5	presents information in a useful format.	
	EUCS6	is user friendly.	
	EUCS7	is easy to use.	
	EUCS8	provides information in a timely manner.	
	EUCS9	provides clear information.	
	EUCS10	provides up to date information.	

APPENDIX B: INDUSTRY REPRESENTATION OF SURVEY SAMPLE



APPENDIX C: CHARACTERISTICS OF THE SURVEY SAMPLE

Gender	**Freq.**	**%**
Male	159	62%
Female	59	23%
Missing	40	16%
Highest level of education	**Freq.**	**%**
High School / GED	3	1%
Some College	7	3%
2-year College Degree	8	4%
4-year College Degree	96	45%
Masters Degree	93	43%
Doctoral Degree	11	5%
Missing	40	16%
Years of experience in current profession	**Freq.**	**%**
< 1 year	5	2%
1 - 5 years	41	16%
6 - 10 years	38	15%
11 - 15 years	42	16%
16 - 20 years	34	13%
> 20 years	58	22%
Missing	40	16%
Approx. number of total employees in organization	**Freq.**	**%**
1-49	25	10%
50-100	11	4%
101- 300	17	7%
301 - 500	15	6%
501 - 1000	24	9%
>1000	126	49%
Missing	40	16%
Primary functional area	**Freq.**	**%**
Quality	40	28%
Research and Development	27	19%
Design	22	16%
Production	21	15%
Human Resources	8	6%
Sales	8	6%
Customer Service	6	4%
Finance	6	4%
Warranty	3	2%
Other	77	55%
Missing	40	28%

APPENDIX D: COMMON METHOD BIAS (CMB) ANALYSIS

Construct	Indicator	Substantive Factor Loading	Variance Explained	Method Factor Loading	Variance Explained
CON - Continuance of use	CON1	0.63	0.40	-0.12	0.01
	CON2	0.92	0.85	-0.04	0.00
	CON3	0.91	0.82	0.02	0.00
	CON4	0.81	0.66	0.10	0.01
EUCS - End User Computing Satisfaction	EUCS1	0.76	0.58	0.10	0.01
	EUCS2	0.66	0.44	0.16	0.03
	EUCS3	0.80	0.65	0.02	0.00
	EUCS4	0.83	0.70	-0.08	0.01
	EUCS5	0.88	0.77	-0.06	0.00
	EUCS6	0.79	0.62	0.07	0.00
	EUCS7	0.87	0.76	-0.14	0.02
	EUCS8	0.80	0.64	-0.05	0.00
	EUCS9	0.74	0.55	0.02	0.00
	EUCS10	0.88	0.77	-0.06	0.00
ITS - Information Technology Support	ITS1	0.82	0.67	-0.09	0.01
	ITS2	0.87	0.76	0.01	0.00
	ITS3	0.86	0.73	0.07	0.01
KRU - Knowledge Reuse	KRU1	0.88	0.77	-0.01	0.00
	KRU2	0.81	0.66	0.07	0.01
	KRU3	0.66	0.43	0.17	0.03
	KRU4	0.83	0.69	-0.10	0.01
	KRU5	0.94	0.87	-0.14	0.02
KS - Knowledge Sharing	KS1	0.81	0.66	0.01	0.00
	KS2	0.86	0.73	0.00	0.00
	KS3	0.86	0.73	-0.02	0.00
	KS4	0.44	0.19	0.02	0.00
LC - Learning Culture	LC1	0.72	0.52	0.08	0.01
	LC2	0.91	0.84	-0.08	0.01
	LC3	0.68	0.46	0.13	0.02
	LC4	0.75	0.56	0.04	0.00
	LC5	0.93	0.87	-0.15	0.02
PER - Performance	PER1	0.90	0.80	-0.08	0.01
	PER2	0.76	0.58	0.07	0.01
	PER3	0.76	0.58	0.11	0.01
	PER4	0.88	0.78	-0.05	0.00
	PER5	0.86	0.75	-0.05	0.00
KMST - Strategic Knowledge Orientation	KMST1	0.80	0.64	0.01	0.00
	KMST2	0.78	0.62	0.01	0.00
	KMST3	0.90	0.82	-0.14	0.02
	KMST4	0.86	0.75	-0.02	0.00
	KMST5	0.83	0.69	-0.03	0.00
	KMST6	0.75	0.57	0.09	0.01
	KMST7	0.70	0.49	0.08	0.01
WIC - Worker Interaction & Collaboration	WIC1	0.87	0.76	-0.07	0.01
	WIC2	0.85	0.72	-0.03	0.00
	WIC3	0.79	0.63	-0.07	0.01
	WIC4	0.86	0.73	-0.08	0.01
	WIC5	0.50	0.25	0.34	0.12
Average		0.80	0.66	0.00	0.01

*p<0.025, **p<0.01, ***p<0.005

APPENDIX E: DESCRIPTIVE STATISTICS BY ITEM

Construct	Indicator	Mean	Std. Err	Std. Dev.	Skewness	Kurtosis
CON - Continuance of use	CON1	6.22	0.09	1.48	-2.58	6.10
	CON2	6.27	0.06	1.01	-2.23	6.40
	CON3	4.42	0.04	0.72	-1.50	3.35
	CON4	4.37	0.05	0.73	-1.36	2.84
EUCS - End User Computing Satisfaction	EUCS1	3.39	0.05	0.86	-0.18	-0.08
	EUCS2	3.70	0.05	0.78	-0.81	1.41
	EUCS3	3.55	0.05	0.87	-0.57	0.28
	EUCS4	3.67	0.05	0.84	-0.54	0.39
	EUCS5	3.67	0.05	0.79	-0.71	0.85
	EUCS6	3.69	0.05	0.78	-0.44	-0.02
	EUCS7	3.46	0.06	0.93	-0.59	-0.02
	EUCS8	3.54	0.06	0.94	-0.52	-0.32
	EUCS9	3.76	0.05	0.77	-0.67	0.88
	EUCS10	3.55	0.05	0.86	-0.36	0.17
ITS - Information Technology Support	ITS1	3.59	0.06	1.02	-0.61	-0.32
	ITS2	3.61	0.06	0.99	-0.52	-0.35
	ITS3	3.68	0.06	0.94	-0.71	-0.08
KRU - Knowledge Reuse	KRU1	3.86	0.04	0.71	-0.82	1.48
	KRU2	3.77	0.04	0.72	-0.93	1.73
	KRU3	3.77	0.04	0.71	-0.98	1.96
	KRU4	3.59	0.05	0.79	-0.36	0.04
	KRU5	3.86	0.05	0.75	-0.91	1.37
KS - Knowledge Sharing	KS1	3.77	0.05	0.80	-0.89	0.99
	KS2	3.79	0.04	0.70	-0.57	0.52
	KS3	3.87	0.04	0.68	-0.72	1.10
	KS4	4.48	0.04	0.65	-1.35	2.39
LC - Learning Culture	LC1	3.53	0.06	0.99	-0.38	-0.61
	LC2	3.85	0.05	0.82	-0.71	0.48
	LC3	3.83	0.05	0.84	-0.88	0.96
	LC4	3.79	0.05	0.79	-0.66	0.55
	LC5	3.48	0.06	0.91	-0.42	-0.17
PER - Performance	PER1	4.12	0.04	0.63	-0.45	0.66
	PER2	4.10	0.04	0.68	-1.05	2.70
	PER3	4.01	0.04	0.72	-0.77	1.44
	PER4	3.95	0.05	0.73	-0.53	0.36
	PER5	3.91	0.05	0.74	-0.48	0.19
KMST - Strategic Knowledge Orientation	KMST1	3.53	0.06	0.95	-0.61	-0.02
	KMST2	3.59	0.06	1.02	-0.69	-0.12
	KMST3	3.31	0.06	1.00	-0.26	-0.53
	KMST4	3.31	0.06	0.99	-0.26	-0.48
	KMST5	3.21	0.06	1.01	-0.19	-0.51
	KMST6	3.63	0.06	0.96	-0.58	0.10
	KMST7	3.44	0.06	1.03	-0.32	-0.57
WIC - Worker Interaction & Collaboration	WIC1	4.57	0.04	0.71	-2.53	8.94
	WIC2	4.44	0.05	0.76	-2.08	6.41
	WIC3	4.42	0.05	0.77	-1.74	4.14
	WIC4	4.47	0.05	0.77	-2.06	5.79
	WIC5	3.94	0.06	0.90	-0.76	0.25

APPENDIX F: EKR SURVEY

Informed Consent:

Welcome potential survey participant,

My name is Peter Chhim and I am a PhD Candidate in the Industrial and Systems Engineering Department at Wayne State University.

You are being asked to participate in this survey because you are a working professional and have experience utilizing an Electronic Knowledge Repository (EKR). This survey is a part of my dissertation research, and although as a participant in this research study there will be no direct benefit for you, results of the study may benefit the profession by furthering our understanding of the factors that can impede or facilitate "**Knowledge Reuse**" through EKRs. Your responses will be kept confidential and there will be no connection made to you in the results or in future publications.

Additionally, the survey should not take anymore than 15 minutes and is not expected to contain any risk or inconvenience to you. Furthermore, your participation is strictly voluntary and you may choose to withdraw from the survey at any time without penalty. As well, you have the option to receive a summarized copy of the results, and if you should have any questions or comments, please do not hesitate to contact me:

Peter Chhim, PhD Candidate
Industrial and Systems Engineering
Wayne State University
PChhim@wayne.edu
Or my faculty advisor:

Ratna Babu Chinnam
Professor, Graduate Chair, Founding Director for the Global Executive PhD Track
313-577-4846(Phone)
Ratna.Chinnam@wayne.edu

Additionally, If you have any questions or concerns about your rights as a research participant, the Chair of the Institutional Review Board (IRB) can be contacted at (313) 577-1628. If you are unable to contact the research staff, or if you want to talk to someone other than the research staff, you may also call (313) 577-1628 to ask questions or voice concerns or complaints. The contact information for IRB can be found below.

IRB Administration Office
87 East Canfield, 2nd Floor
Phone: (313) 577-1628
Fax: (313) 993-7122

Finally, by clicking on the '**>>**' button and starting the survey, you are verifying that you have read the explanation of the study, and that you agree to participate. You also understand that your participation in this survey is strictly voluntary and you may choose to withdraw at any time.

Does your company have a formal electronic knowledge repository for managing knowledge?

Examples include: A company Intranet, an internal Wikipedia, electronic network drives or databases where information is formally structured and controlled, or specific software used for the purpose of managing knowledge.

- YES
- NO

How many electronic knowledge repositories does your company currently utilize?

- 1
- 2 - 3
- 4 - 8
- 9 - 15
- > 15

Approximately how long has your company's electronic knowledge repository(s) been in use?

- < 1 year
- 1 - 3 years
- 4 - 8 years
- 9 - 15 years
- > 15 years

Approximately how long have you been using your company's electronic knowledge repository(s)?

- < 1 year
- 1 - 3 years
- 4 - 8 years
- 9 - 15 years
- > 15 years

Approximately how many years of experience do you have using electronic knowledge repositories?

- < 1 year
- 1 - 3 years
- 4 - 8 years
- 9 - 15 years
- > 15 years

Where within your company is knowledge being reused? Select all that apply.

- Design and launch of new products and/or processes
- Training
- Continuous Improvement
- Address internal or external customer issues
- Address warranty issues (consumer or field issues)
- Other

Consider the following sources of knowledge. Select all those that are generated within your company.

- Generated during design and launch of new products and/or processes
- Generated from addressing internal or external customer issues
- Generated from addressing warranty issues
- Generated from continuous improvement activities
- Generated from company training
- Generated from external continuing education
- Other

For the following questions: If your company utilizes more than one electronic knowledge repository, please think of ONLY one of them when answering.

To help answer the following questions, consider how the items below apply to your day to day activities at work.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
In my company, I am often required to work with others.	○	○	○	○	○
I discuss my ideas with others within the company.	○	○	○	○	○
During my day to day activities, I often find that my work relates to others in the company.	○	○	○	○	○
Within my company, there is a willingness to collaborate across organizational units.	○	○	○	○	○
Group work is a part of my job responsibilities.	○	○	○	○	○

To help answer the following questions, Intellectual Capital (I.C.) is defined as the combination of your company's human capital (its people and their skills), organizational capital (patents, systems, policies, procedures), and customer capital (brand, reputation, relationships with customers and suppliers).

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Our top leadership supports and engages in an active dialogue about knowledge management.	○	○	○	○	○
We have incorporated strategies regarding IC into strategic thinking and planning.	○	○	○	○	○
I.C. is a competitive asset that our organization actively manages.	○	○	○	○	○
We have clearly defined strategies for building I.C. that have adequate resources and budgets.	○	○	○	○	○
Our organization design is specifically evaluated in terms of how well it supports I.C. application.	○	○	○	○	○
We have adopted explicit measures for assessing and reporting on various forms of I.C.	○	○	○	○	○
We've developed special roles for helping direct and apply I.C. (e.g. 'knowledge managers').	○	○	○	○	○

To help answer the following questions, the term knowledge item is defined as 'actionable information'.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
The knowledge items within our electronic knowledge repository can be relied upon.	○	○	○	○	○
Our electronic knowledge repository maintains knowledge items at an appropriate level of detail.	○	○	○	○	○
Our electronic knowledge repository provides knowledge items that is current enough to meet my needs.	○	○	○	○	○
There are accuracy problems with the knowledge items I obtained from our electronic knowledge repository.	○	○	○	○	○

Our company's IT provides support...

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
for systematic storing and distributing knowledge.	○	○	○	○	○
regardless of time and place.	○	○	○	○	○
for searching and accessing necessary information.	○	○	○	○	○

To help answer the following questions, consider your day to day activities at work and how they apply to the statements below.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
We support open, ready access by employees to the knowledge created in the organization.	○	○	○	○	○
We are good at learning from both our successes and failures.	○	○	○	○	○
Our culture supports sharing and learning from each other.	○	○	○	○	○
Managers view themselves as active learners and teachers.	○	○	○	○	○
Our leadership empowers employees to apply their knowledge to innovative ends.	○	○	○	○	○

Does your company have a review process for contributing to the electronic knowledge repository?

- Yes
- No

To help answer the following questions, consider the contribution process for your company's Electronic Knowledge Repository (EKR).

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Overall, the contribution review process is clear.	○	○	○	○	○
Getting contributions for the EKR approved and accepted is easy.	○	○	○	○	○
It is easy for me to see the status of my contributions to the EKR.	○	○	○	○	○
The review process for contributions to the EKR occur in a timely manner.	○	○	○	○	○
My contributions to the EKR often end up being rejected.	○	○	○	○	○

To help answer the following questions, consider the usefulness of the knowledge items obtained from your company's Electronic Knowledge Repository (EKR). As a reminder, a knowledge item is defined as 'actionable information'.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I reuse knowledge from the EKR to help me reduce training time for new staff.	○	○	○	○	○
I often reuse knowledge from the EKR.	○	○	○	○	○
I am often able to apply the knowledge from the EKR to my work.	○	○	○	○	○
I reuse knowledge from the EKR to help me prevent issues.	○	○	○	○	○
I reuse knowledge from the EKR to help me reduce the time I spend on addressing issues.	○	○	○	○	○

Employees at our company...

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
provide material and methodologies to other team members.	○	○	○	○	○
share their experiences or know-how with other team members.	○	○	○	○	○
share their work reports and official documents with other team members.	○	○	○	○	○

I often share information with other employees within the company.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
○	○	○	○	○

What is the likelihood that you would continue using the electronic knowledge repository?

- ○ Very Unlikely
- ○ Unlikely
- ○ Somewhat Unlikely
- ○ Undecided
- ○ Somewhat Likely
- ○ Likely
- ○ Very Likely

If faced with a similar issue or situation in the future, I would use the electronic knowledge repository again.

Very Unlikely	Unlikely	Somewhat Unlikely	Undecided	Somewhat Likely	Likely	Very Likely
○	○	○	○	○	○	○

I would recommend the use of the electronic knowledge repository to my colleagues at work.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
○	○	○	○	○

I intend to continue using the electronic knowledge repository as a part of my daily activities.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
○	○	○	○	○

Using the electronic knowledge repository...

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
helps me to provide more relevant knowledge to my customers and/or my managers.	○	○	○	○	○
helps me to improve products and processes.	○	○	○	○	○
allows me to reduce the time I spend on addressing issues.	○	○	○	○	○
helps me to prevent issues.	○	○	○	○	○
helped prevent me from making the same mistakes others made.	○	○	○	○	○

I feel the electronic knowledge repository...

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
provides sufficient information.	○	○	○	○	○
is accurate.	○	○	○	○	○
provides up to date information.	○	○	○	○	○
is easy to use.	○	○	○	○	○
has content that meets my needs	○	○	○	○	○
is user friendly.	○	○	○	○	○
provides the precise information I need.	○	○	○	○	○
provides clear information	○	○	○	○	○
provides information in a timely manner.	○	○	○	○	○
presents information in a useful format.	○	○	○	○	○

What is your gender?

○ Male

○ Female

What is the highest level of education you have completed?

- ○ Less than High School
- ○ High School / GED
- ○ Some College
- ○ 2-year College Degree
- ○ 4-year College Degree
- ○ Masters Degree
- ○ Doctoral Degree
- ○ Professional Degree (JD, MD)

How many years of work experience do you have in your current profession?
Ex., 3 years as an engineer.

- ○ < 1 year
- ○ 1 - 5 years
- ○ 6 - 10 years
- ○ 11 - 15 years
- ○ 16 - 20 years
- ○ > 20 years

Approximately, how many total employees work for your organization (include international locations as well)?

- ○ 1-49
- ○ 50-100
- ○ 101- 300
- ○ 301 - 500
- ○ 501 - 1000
- ○ >1000

What primary functional area of the company do you work in?

- Production
- Sales
- Research and Development
- Customer Service
- Finance
- Human Resources
- Quality
- Design
- Warranty
- Other

In what type of industry do you work?

- Agriculture
- Banking / Finance
- Communication
- Education
- Government
- Healthcare
- Hospitality
- Insurance
- Manufacturing
- Retail
- Software
- Transportation
- Other

APPENDIX G: EKR STUDY CONCURRENCE OF EXEMPTION

WAYNE STATE UNIVERSITY

IRB Administration Office
87 East Canfield, Second Floor
Detroit, Michigan 48201
Phone: (313) 577-1628
FAX: (313) 993-7122
http://irb.wayne.edu

CONCURRENCE OF EXEMPTION

To: Peter Chhim
Industrial and Systems Engineering

From: Dr. Deborah Ellis M. K[illegible] / PB.
for Chairperson, Behavioral Institutional Review Board (B3)

Date: January 13, 2014

RE: IRB #: 116213B3X

Protocol Title: Knowledge Reuse in the Manufacturing Industry

Sponsor:

Protocol #: 1311012569

The above-referenced protocol has been reviewed and found to qualify for **Exemption** according to paragraph #2 of the Department of Health and Human Services Code of Federal Regulations [45 CFR 46.101(b)].

- Revised Social/Behavioral/Education Exempt Protocol Summary Form (received in the IRB Office 12/2/2013)
- Internet Information Sheet (dated 12/2/2013)
- Data Collection Tool: Qualtrics Survey

This proposal has not been evaluated for scientific merit, except to weigh the risk to the human subjects in relation to the potential benefits.

- Exempt protocols do not require annual review by the IRB.
- All changes or amendments to the above-referenced protocol require review and approval by the IRB **BEFORE** implementation.
- Adverse Reactions/Unexpected Events (AR/UE) must be submitted on the appropriate form within the timeframe specified in the IRB Administration Office Policy (http://irb.wayne.edu/policies-human-research.php).

NOTE: Forms should be downloaded from the IRB Administration Office website http://irb.wayne.edu at each use.

APPENDIX H: EKR STUDY NOTICE OF EXPEDITED AMENDMENT APPROVAL

WAYNE STATE UNIVERSITY

IRB Administration Office
87 East Canfield, Second Floor
Detroit, Michigan 48201
Phone: (313) 577-1628
FAX: (313) 993-7122
http://irb.wayne.edu

NOTICE OF EXPEDITED AMENDMENT APPROVAL

To: Peter Chhim
Industrial and Systems Engineering

From: Dr. Deborah Ellis or designee ____________________
Chairperson, Behavioral Institutional Review Board (B3)

Date: February 10, 2014

RE: IRB #: 116213B3X

Protocol Title: Knowledge Reuse through Electronic Knowledge Repositories

Funding Source:

Protocol #: 1311012569

Expiration Date:

The above-referenced protocol amendment, as itemized below, was reviewed by the Chairperson/designee of the Wayne State University Institutional Review Board (B3) and is APPROVED effective immediately.

- Protocol - Data Collection instrument revised to reflect replacement of 10 questions pertaining to perceived information quality and ease of use with 10 questions based on end user computing satisfaction.
- Consent Form - Informed Consent (revision received 1/29/2014) - Consent Form modified to reflect removal of reference to the 'manufacturing industry' and instead will just reference 'industry'.

REFERENCES

Aggestam, L., Durst, S., & Persson, A. (2014). Critical Success Factors in Capturing Knowledge for Retention in IT Supported Repositories. *Information, 5*(4), 558-569.

Agyapong-Kodua, K., Lohse, N., Darlington, R., & Ratchev, S. (2015). Review of Semantic Modelling Technologies in Support of Virtual Factory Design. *International Journal of Production Research, 51*(14), 4388-4404.

Ahmed, S., Kim, S., & Wallace, M. K. (2007). A Methodology for Creating Ontologies for Engineering Design. *Journal of Computing and Information Science in Engineering, 7*(2), 134-140.

AIAG. (2008a). *Advanced Product Quality Planning and Control Plan (APQP).* Southfield: Automotive Automotive Industry Action Group.

AIAG. (2008b). *Potential Failure Mode and Effects Analysis (FMEA)* (Fourth Edition ed.). Southfield: Automotive Industry Action Group.

Akgun, A. E., Byrne, J., Keskin, H., Lynn, G. S., & Imamoglu, S. Z. (2005). Knowledge networks in new product development projects: a transactive memory perspective. *Information & Management, 42*(8), 1105-1120.

Alavi, M., & Leidner, D. E. (1999). Knowledge Management Systems: Issues, Challenges, and Benefits. *Communications of the AIS, 1*(7).

Alavi, M., & Leidner, D. E. (2001). Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues. *MIS Quarterly, 25*(1), 107-136.

Antonakis, J., Bendahan, S., Jacquart, P., & Lalive, R. (2010). On making causal claims: A review and recommendations. *Leadership Quarterly, 21*(6), 1086-1120.

Bagozzi, R. P., & Yi, Y. (1988). On the Evaluation of Structural Equation Models. *Journal of the Academy of Marketing Science, 16*(1), 74-94.

Ball, L., & Harris, R. (1982). SMIS members: a membership analysis. *MIS Quarterly*, *6*(1), 19-38.

Bechhofer, S., van Harmelen, F., Hendler, J., Horrocks, I., McGuiness, L. D., Patel-Schneider, F., & Stein, A. L. (2004, 02 10). *www.w3.org.* Retrieved from OWL Web Ontology Lanugague Reference: http://www.w3.org/TR/owl-ref/

Bechhofer, S., van Harmelen, F., Hendler, J., Horrocks, I., McGuiness, L. D., Patel-Schneider, F., & Stein, A. L. (2012, 12 11). *www.w3.org.* Retrieved from OWL 2 Web Ontology Language Document Overview (Second Edition): http://www.w3.org/TR/owl2-overview/#Overview

Bhattacherjee, A. (2001). Understanding Information Systems Continuance: An Expectation-Confirmation Model. *MIS Quarterly, 25*(3), 351 - 370.

Blau, P. M. (1964). *Exchange and power in social life.* New Brunswick, NJ: Wiley.

Bobrek, M., & Sokovic, M. (2005). Implementation of APQP - concept in design of QMS. *Journal of Materials Processing Technology, 162/163*, 718-724.

Bock, G. W., Mahmood, M., Sharma, S., & Kang, Y. J. (2010). The impact of information overload and contribution overload on continued usage of electronic knowledge repositories. *Journal of Organizational Computing and Electronic Commerce, 20*(3), 257-278.

Boh, F. (2008). Reuse of knowledge assets from repositiories: A mixed methods study. *Information and Management, 45*(6), 365-375.

Borst, W. (1997). *Construction of Engineering Ontologies.* PhD Thesis, University of Tweenty, Enschede, NL.

Calantone, R. J., Cavusgil, S. T., & Zhao, Y. (2002). Learning orientation, firm innovation capability, and firm performance. *Industrial marketing management, 31*(6), 515-524.

Cassanelli, G., Mura, G., Fantini, F., Vanzi, M., & Plano, B. (2006). Failure analysis-assisted FMEA. *Microelectronics Reliability, 46*(9), 1795-1799.

Chandrasegaran, S. K., Ramani, K., Sriram, R. D., Horvath, I., Bernard, A., Harik, R. F., & Gao, W. (2013). The evolution, challenges, and future of knowledge representation in product design systems. *Computer-Aided Design, 45*(2), 204-228.

Chang, K. H., & Wen, T. C. (2010). A novel efficient approach for DFMEA combining 2-tuple and the OWA operator. *Expert Systems with Applications*, 2362-2370.

Chang, X., Rai, R., & Terpenny, J. (2010). Development and utlization of ontologies for manufacturing. *Journal of mechanical design, 132*(2), 1-12.

Chase, R. L. (1997). The knowledge-based organization: An international survey. *Journal of Knowledge Management, 1*(1), 38-49.

Chin, W. W. (1998). The partial least squares approach to structural equation modeling. In G. Marcoulides, *Modern Methods for Business Research* (pp. 295-336). G.A.: Lawrence Erlbaum Publishing.

Chin, W. W. (2010). How to write up and report PLS analyses. In *Handbook of partial least squares* (pp. 655-690). Berlin Heidelberg: Springer.

Choi, B., Poon, S. K., & Davis, J. G. (2008). Effects of knowledge management strategy on organizational performance: A complementarity theory-based approach. *Omega*, *36*(2), 235-251.

Choi, M. S., & Durcikova, A. (2014). Are Printed Documents Becoming Irrelevant? The Role of Perceived Usefulness of Knowledge Repositories in Selecting From Knowledge Sources. *Communications of the Association for Information Systems, 34*(38), 751-774.

Choi, S. Y., Lee, H., & Yoo, Y. (2010). The Impact of Information Technology and Transactive Memory Systems on Knowledge Sharing, Application, and Team Performance: A Field Study. *MIS Quarterly*, *34*(4), 855-870.

Coveo and TSIA. (2014). *The State of Knowledge Management: 2014.* San Diego, CA: TSIA.

Crowley, A. (1997). Memory bank: Companies try to record the knowledge of their information workers. *PC Week*, *14*, 101-102.

Davenport, T. H., & Prusak, L. (1998). *Working Knowledge: How organizations manage what they know*. Harvard Business Press.

Davis, F. D. (1989). Perceived Usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319-340.

Desouza, K., & Evaristo, R. (2003). Global Knowledge Management Strategies. *European Management Journal*, *21*(1), 62-67.

Devellis, R. (2011). *Scale Development.* Thousand Oaks, CA: Sage Publications.

Dierickx, I., & Cook, K. (1989). Asset stock accumulation of competitve advantage. *Management Science, 35*(12), 1504-1511.

Dijoux, C. (2015, September 29). *Edgar Schein : Organizational Culture and Leadership*. Retrieved from Thehypertextual.com: http://thehypertextual.com/2013/01/17/edgar-schein-organizational-culture-and-leadership/

Dittmann, L., Rademacher, T., & Zelewski, S. (2004). Performing FMEA using ontologies. *18th International Workshop on Qualitative Reasoning*, (pp. 209-216). Evanston, USA.

Dixon, N. M. (2000). Common Knowledge: How campanies thrive by sharing what they know. *Harvard Business School Press*, Boston, Massachusetts.

Doll, W. J., & Torkzadeh, G. (1998). The Measurement of end-user computing satisfaction. *MIS quarterly*, *12*(2), 259-274.

Droege, S. B., & Hoobler, J. M. (2003). Employee Turnover and Tacit Knowledge Diffusion: A Network Perspective. *Journal of Managerial Issues, 15*(1), 50-64.

Ducharme, B. (2013). *Learning SPARQL* (Second ed.). Sebastopol: O'Reilly Media Inc.

Durcikova, A., & Gray, P. (2009). How Knowledge Validation Processes Affect Knowledge Contribution. *Journal of Management Information Systems*, *25*(4), 81-107.

Ebrahimimpour, V., Rezaie, K., & Shokravi, S. (2010). An ontology approach to support FMEA studies. *Expert Systems with Applications, 37*(1), 671-677.

Ettlie, J. E., & Kubarek, M. (2008). Design Reuse in Manufacturing and Services. *Journal of Product Innovation Management, 25*(5), 457-472.

Fadel, K. J., & Durcikova, A. (2014). If it's fair, I'll share: The effect of perceived knowledge validation justice on contributions to an organizational repository. *Information & Management*, *51*(5), 511-519.

Fernandez-Lopez, M., Gomez-Perez, A., & Juristo, N. (1997). METHONOLOGY: From Ontological Art Towards Ontological Engineering. *AAAI Symposium on Ontological Engineering*, (pp. 33-40). Stanford, CA.

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of marketing research, 18*(1), 39-50.

Fulk, J., Flanagin, A. J., Kalman, M. E., Monge, P. R., & Ryan, T. (1996). Connective and communal public goods in interative communication systems. *Communication Theory, 6*(1), 60-87.

Geisser, S. (1975). The predictive sample reuse method with applications. *Journal of American Statistical Association, 70*(350), 320-328.

Gennari, J. H., Musen, M. A., Fergerson, R. W., Grosso, W. E., Crubezy, M., Eriksson, H., . . . Tu, S. W. (2003). The evolution of Protege-2000: An environment for knowledge-based systems development. *International Journal of Human-Computer Studies, 58*(1), 89-123.

Goh, N. (2010). Six Sigma in Industry: Some Observations After Twenty-five Years. *Quality and Reliability Engineering International, 27*(2), 221-227.

Gold, A. H., & Arvind Malhotra, A. H. (2001). Knowledge management: An organizational capabilities perspective. *Journal of management information systems, 18*(1), 185-214.

Gotz, O., Liehr-Gobbers, K., & Krafft, M. (2010). Evaluation of structural equation models using partial least squares (PLS) approach. In V. a. Vinzi, *Handbook of Partial Least Squares* (pp. 691-711). Springer.

Gurteen, D. (2015). Knowledge cafe. *Inside Knowledge, 13*(3), 8-13.

Hair Jr, J. F., Hult, G. T., Ringle, C., & Sarstedt, M. (2013). *A primer on partial least squares structural equation modeling (PLS-SEM).* Sage Publications.

Hair Jr., J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis: A global perspective* (7th ed. ed.). Upper Saddle River: Pearson.

Hanh, J., & Subramani, M. R. (2000). A framework of knowledge management systems: Issues and challenges for theory and practice. *Proceedings of the 21st International Conference on Information Systems*, (pp. 302-312). Brisbane, Australia.

Hansen, M. T. (2002). Knowledge networks: Explaining effective knowledge sharing in multiunit companies. *Organization science*, *13*(3), 232-248.

Hansen, M.T.; Nohria, N.; Tierney, T. (1999). What's your strategy for managing knowledge. *Harvard Business Review, 77*(2), 106-116.

He, W., & Wei, K. K. (2009). What drives continued knowledge sharing? An investigation of knowledge-contribution and -seeking beliefs. *Decision Support Systems*, *46*(4), 826-838.

Hedlund, G. (1994). A model of knowledge management and the N-form corporation. *Strategic management journal*, *15*(S2), 73-90.

Holsapple, C. W., & Joshi, K. D. (2001). Organizational knowledge resources. *Decision support systems, 31*(1), 39-54.

Horridge, M., Knublauch, H., Rector, A., Stevens, R., & Wroe, C. (2004). *A Practical Guide to Building OWL Ontologies Using The Protege-OWL Plugin and CO-ODE Tools.* Edition 1.0, University of Manchester.

Huber, G. P. (1991). Organizational learning: The contributing processes and the literatures. *Oganizational science, 2*(1), 88-115.

Hurley, R. F., & Hult, G. T. (1998). Innovation, market orientation, and organizational learning: an integration and empirical examination. *Journal of Marketing, 62*(3), 42-54.

ISO. (2014). *The ISO Survey of Management System Standard - 2013*. Retrieved August 11, 2015, from www.iso.org: http://www.iso.org/iso/iso_survey_executive-summary.pdf?v2013

Iyer, N., Jayanit, S., Lou, K., Kalyanaraman, Y., & Ramani, K. (2005). Shape-based searching for product lifecycle applications. *Computer-Aided Design*, *37*(13), 1435-1446.

Jamrog, J. (2004). The perfect store: The future of retention and engagment. *People and Strategy, 27*(3), 26-33.

Janz, B. D., & Prasarnphanich, P. (2003). Understanding the antecedents of effective knowledge management: The Importance of a knowledge-centered culture. *Decision sciences, 34*(2), 351-384.

Kang, H. (2013, April 09). *Why Personal Interaction Drives Innovation and Collaboration.* Retrieved from Forbes: http://www.forbes.com/sites/skollworldforum/2013/04/09/why-personal-interaction-drives-innovation-and-collaboration/

Kankanhalli, A., Lee, O. K., & Lim, K. H. (2011). Knowledge reuse through electronic repositories: A study in the context of customer service support. *Information & Management, 48*(2), 106-113.

Kankanhalli, A., Tan, B. C., & Wei, K. K. (2005a). Contributing knowledge to electronic knowledge repositories: an empirical investigation. *MIS quarterly, 29*(1), 113-143.

Kankanhalli, A., Tan, B. C., & Wei, K. K. (2005b). Understanding seeking from electronic knowledge repositories: An empirical study. *Journal of the American Society for Information Science and Technology, 56*(11), 1156-1166.

Khadilkar, D. V., & Stauffer, L. A. (1996). An experimental evaluation of design information reuse during conceptual design. *Journal of Engineering Design, 7*(4), 331.

Kim, K. Y., Manley, D. G., & Yang, H. (2006). Ontology-based assembly design and information sharing for collaborative product development. *Computer-Aided Design, 38*(12), 1233-1250.

Kimble, C. (2013). What cost knowledge management? The example of Infosys. *Global Business and Organizational Excellence, 32*(3), 6-14.

Kitamura, Y., & Mizoguchi, R. (2004). Ontology-based systemization of functional knowledge. *Journal of Engineering Design, 15*(4), 327-351.

Kline, R. B. (1998). *Principles and Practice of Structural Equation Modeling.* NY: Guilford Press.

Laaroussi, A., Fies, B., Vankeisbelckt, R., & Hans, j. (2007). Ontology-aided FMEA for construction products. *24th W78 Conference Maribor*, *26,* pp. 189-194.

Lansdale, M. W. (1998). The psychology of personal information management. *Applied Ergonomics, 19*(1), 55-66.

Lee, B. H. (2001). Using FMEA models and ontologies to build diagnostic models. *AI EDAM, 15*(4), 281-293.

Lee, B. T. (1998, 10 14). Why RDF model is different from the XML model. Retrieved 06 28, 2015, from http://www.w3.org/DesignIssues/RDF-XML

Lee, H., & Choi, B. (2003). Knowledge management enablers, processes, and organizational performance: An Integrative view and empirical examination. *Journal of management information systems, 20*(1), 179-228.

Lee, S., Kim, B., & Kim, H. (2012). An integrated view of knowledge management for performance. *Journal of Knowledge Management, 16*(2), 183-203.

Lee-Kelley, L., Blackman, D. A., & Hurst, J. P. (2007). An exploration of the relationship between learning organizations and the retention of knowledge workers. *The Learning Organization*, *14*(3), 204-221.

Lei, D., Hitt, M. A., & Bettis, R. (1996). Dynamic core competences through meta-learning and strategic context. *Journal of management, 22*(4), 549-569.

Li, Z., Yang, M. C., & Ramni, K. (2009). A methodology for engineering ontology acquisition and validation. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 23*(01), 37-51.

Liang, H., Saraf, N., Hu, Q., & Xue, Y. (2007). Assimilation of enterprise systems: the effect of institutional pressures and the mediating role of top management. *MIS quarterly, 31*(1), 59-87.

Liao, H., & Chuang, A. (2004). A multilevel investigation of factors influencing employee service performance and customer outcomes. *Academy of Management Journal, 47*(1), 41-58.

Liebowitz, J., & Beckman, T. J. (1998). *Knowledge organizations: What every manager should know.* Boca Raton: CRC Press.

Lin, F., Zhang, Y., Lou, C., Chu, Y., & Cai, M. (2011). Developing manufacturing ontologies for knowledge reuse in distributed manufacturing environment. *International Journal of Production Research, 49*(2), 343-359.

Lin, H. K., & Harding, J. A. (2007). A manufacturing system engineering ontology model on the semantic web for inter-enterprise collaboration. *Computers in Industry, 58*(5), 428-437.

Lin, H. K., Harding, J. A., & Shahbaz, M. (2004). Manufacturing system engineering ontology for semantic interoperability across extended project teams. *International journal of production research, 42*(24), 5099-5118.

Lin, H., & Fan, W. (2012). EXAMINING COMMITMENT IN ELECTRONIC KNOWLEDGE REPOSITORY USAGE. *Journal of Computer Information Systems, 52*(4), 88-97.

Lopez-Nicolas, C., & Merono-Cerdan, A. L. (2011). Strategic knowledge management, innovation and performance. *International journal of information management*, *31*(6), 502-509.

Maedche, A., & Staab, S. (2001). Ontology learning for the semantic web. *IEEE Intelligent systems*, *16*(2), 72-79.

Maglitta, J. (1996). Smarten up! *Computerworld*, *29*(23), 84-86.

Markus, L. M. (2001). Toward a theory of knowledge reuse: Types of knowledge reuse situations and factors in reuse success. *Journal of management information systems*, *18*(1), 57-93.

Martinez-Cruz, C., Blanco, I. J., & Vila, M. A. (2012). Ontologies versus relational databases: are they so differnt? A comparison. *Artificial Intelligence Review*, *38*(4), 271-290.

McCann, J. E., & Buckner, M. (2004). Strategically integrating knowledge management initiatives. *Journal of Knowledge Management*, *8*(1), 47-63.

Mcgreevy, M. (2007). *The Knowledge Management Spending Report.* Stamford, CT: AMR Research.

Mcgreevy, M. (2007). *The Knowledge Management Spending Report* . AMR Research.

Mitch Casselman, R., & Samson, D. (2007). Aligning knowledge strategy and knowledge capabilities. *Technology Analysis & Strategic Management*, *19*(1), 69-81.

Molhanec, M., Zhuravskaya, O., Povolotskaya, E., & Tarba, L. (2011). The ontology based FMEA of lead free soldering process. *34th International Spring Seminar* (pp. 267-273). IEEE.

NASA. (2015, 05 15). …And Now Featuring the New Lessons Learned Landing Page. (E. L. Bonilla, Ed.) Retrieved from http://km.nasa.gov/and-now-featuring-the-new-lessons-learned-landing-page/

Nelson, K., & McCann, J. E. (2010). Designing for knowledge worker retention & organizational performance. *Journal of Management and Marketing Research, 1*, 1-18.

Nicolaou, A. I., & McKnight, D. H. (2006). Perceived information quality in data exchanges: Effects on risk, trust and intention to use. *Information Systems Research, 17*(4), 332-351.

Nonaka, I. (1994). A dynamic theory of organizational knowledge creation. *Organization Science, 5*(1), 14-37.

Noy, N. F., & McGuinness, D. L. (2001). *What is an ontology and why we need it*. Retrieved from Ontology Development 101: A Guide to Creating Your First Ontology: http://liris.cnrs.fr/alain.mille/enseignements/Ecole_Centrale/What%20is%20an%20ontology%20and%20why%20we%20need%20it.htm

Offsey, S. (1997). Knowledge management: linking people to knowledge for bottom line results. *Journal of Knowlege Management, 1*(2), 113-122.

Palmes, P. (2014). A New Look: 15 things you must know about the upcoming ISO 9001 revision. *Quality Progress, September 2014*, 19-21.

Pavlouv, P. A., Liang, H., & Xue, Y. (2006). Understanding and mitigating uncertainty in online exchange relationships: a principal-agent perspective. *MIS quarterly, 31*(1), 105-136.

Perez-Bustamante, G. (1999). Knowledge management in agile innovative organizations. *Journal of knoweldge management, 3*(1), 6-17.

Pinto, H., & Martins, J. (2004). Ontologies: How Can They Be Built? *Knowledge and Information Systems, 6*(4), 441-464.

Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: a critical review of the literature and recommended remedies. *Journal of applied psychology, 88*(5), 879-903.

Preacher, K. J., & Hayes, A. F. (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behavior research methods, instruments & computers, 36*(4), 717-731.

Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior research methods, 40*(3), 879-891.

Royce, W. W. (1970). Managing the development of large software systems. *In Proceedings, IEEE WESCON*, *26*, pp. 1-9.

Sahoo, S. S., Halb, W., Hellmann, S., Idehen, K., Thibodeau Jr., T., Auer, S., . . . Ezzat, A. (2009). *A survey of current approaches for mapping of relational databases to RDF*. W3C RDB2RDF Incubator Group Report.

Saito, A., Umemoto, K., & Ikeda, M. (2007). A strategy-based ontology for knowledge management technologies. *Journal of knowlege Management, 11*(1), 97-114.

Sambamurthy, V., Bharadwaj, A., & Grover, V. (2003). Shaping agility through digital options: Reconceptualizing the role of information technology in contemporary firms. *MIS quarterly, 27*(2), 237-263.

Sanya, O. I., & Shehab, M. E. (2015). A framework for developing engineering design ontologies within the aerospace industry. *International Journal of Production Research, 53*(8), 2383-2409.

Sattler, H., Volckner, F., Riediger, C., & Ringle, C. (2010). The impact of brand extension success drivers on brand extension price premiums. *International Journal of Research in Marketing, 27*(4), 319-328.

Schein, H. E. (2010). *Organizational Culture and Leadership* (Vol. 4th Edition). San Fransicso: John Wiley & Sons.

Shahin, T. M., Andrews, P. T., & Sivaloganathan, S. (1999). A design reuse system. *Proceedings of the Institution of Mechanical Engineers, Part B. 213*, pp. 621-627. Journal of Engineering Manufacture.

Shearer, R., Motik, B., & Horrocks, I. (2008). HermiT: A Highly-Efficient OWL Reasoner. *OWLED, 432*.

Sheehan, K. B., & McMillan, S. J. (1999). Response variation in e-mail surveys: An exploration. *Journal of advertising research, 39*(4), 45-54.

Siponen, M., & Vance, A. (2010). Neurtralization: new insights into the problem of employee information systems security policy violations. *MIS quarterly, 34*(3), A1-A12.

Slater, S. F., & Narver, J. C. (1994). Does competitve environment moderate the market orientation-performance relationship? *The Journal of Marketing, 58*(1), 46-55.

Stanford Center for Biomedical Research. (2015, 01 03). Protege. Retrieved from http://protege.stanford.edu/

Stewart, T., & Ruckdeschel, C. (1988). *Intellectual capital: The new wealth of organizations.* Wiley Online Library.

Stone, M. (1974). Cross-validatory choice and assessment of statistical predictions. *Journal of the Royal Statistical Society, 36*(2), 111-147.

Storey, J., & Barnett, E. (2000). Knowledge management initiatives: Learning from failure. *Journal of Knowledge Management*, *4*(2), 145-156.

Studer, R., Benjamins, V. R., & Fensel, D. (1998). Knowledge engineering: principles and methods. *Data and knowledge engineering*, *25*(1), 161-197.

Swartout, B., Patil, R., Knight, K., & Russ, T. (1996). Toward distributed use of large scale ontologies. *In Proceedings of 10th Knowledge Acquisition for Knowledge - Based Systems Workship.* Banff, Canada.

Tabachnick, B. G., & Fidell, L. S. (2001). *Using multivariate statistics.* Boston: Allyn and Bacon.

Taylor, C. R. (2004). Retention Leadership. *T AND D*, *58*(3), 41-45.

Tha, K. K., & Khet, K. (2010). Examining the Factors Influencing Continued Knowledge Contribution in Electronic Knowledge Repository. *AMCIS 2010 Proceedings.* Paper 548. Retrieved from http://aisel.aisnet.org/amcis2010/548

Thisse, L. (1996). Advanced Quality Planning: A Guide for Any Organization. *Quality Progress*, *31*(2), 73-77.

Trist, E. L., & Bamforth, K. W. (1951). Some social and psychological consequences of the long wall method of coal getting. *Human relations*, *4*(3), 3-39.

Tsai, M. T., Chen, C. C., & Chin, C. W. (2010). Knowledge workers' interpersonal skills and innovation performance: an empirical study of Taiwanese high-tech industrial workers. *Social Behavior and Personality*, *38*(1), 115-126.

Tsarkov, D., & Horrocks, I. (2006). FaCT++ description logic reasonser: System description. In *Automated reasoning* (pp. 292-297). Berlin: Springer Berlin Heidelberg.

Tseng, S. M. (2008). Knowledge management system performance measure index. *Expert Systems with Applications*, *34*(1), 734-745.

Uschold, M., & King, M. (1995). Towards a Methodology for Building Ontologies. *Workshop on Basic Ontological Issues in Knowledge Sharing D (IJCAI'95)*, (pp. 6.1 - 6.10). Montreal, Canada.

Vaccaro, A., Parente, R., & Veloso, F. (2010). Knowledge management tools, inter-organizational relationships, innovation and firm performance. *Technological Forecasting & Social Change, 77*(7), 1076-1089.

W3C. (2012, 12 23). OWL Working Group. Retrieved 06 28, 2015, from http://www.w3.org/2007/OWL/wiki/OWL_Working_Group

W3Ca. (2014, 12 30). *W3C Semantic Web Activity*. Retrieved from W3C: http://www.w3.org/2001/sw/

W3Cb. (2015, January 5). *OWL 2 Web Ontology Language*. Retrieved from W3C Recommendation: http://www.w3.org/TR/2009/REC-owl2-syntax-20091027/#Ontology_IRI_and_Version_IRI

W3Cc. (n.d.). *W3C*. Retrieved from SPARQL Query Language for RDF: http://www.w3.org/TR/rdf-sparql-query/

Walker, S. L., & Fraser, B. J. (2005). Development and validation of an instrument for assessing distance education learning environments in higher education: The Distance Education Learning Environments Survey (DELES). *Learning Environments Research, 8*(3), 289-308.

Wasko, M. M., & Faraj, S. (2005). Why should I share? Examing social capital and knowledge contribution in electronic networks of practice. *MIS quarterly*, *29*(1), 35-57.

Watson, S., & Hewett, K. (2006). A Multi-Theoretical Model of Knowledge Transfer in Organization: Determinants of Knowledge Contribution and Knowledge Reuse. *Journal of management studies, 43*(2), 141-173.

Wayne State University. (2015, October 10). *Doctor of Philosophy - Global Executive Track.* Retrieved from www.wayne.edu: http://engineering.wayne.edu/ise/get/

Wenger, E., McDermott, R., & Snyder, W. M. (2002). *A guide to managing knowledge: cultivating communities of practice.* Boston, Massachusetts: Harvard Business School Press.

Whitworth, B. (2006). Socio-technical systems. In C. Ghaoui (Ed.), *Encyclopedia of Human Computer Interaction* (pp. 533-541). London, U.K.: Idea Group Reference.

Wold, H. (1982). Soft Modeling: The Basic Design and Some Extensions. In K. Joreskog, & H. Wold (Eds.), *Systems Under Indirect Observations - Causalit, Structure, Prediction* (Vol. 2, pp. 1-54). Amsterdam, North Holland.

Xiuxu, Z., & Yuming, Z. (2012). Application Research of Ontology - enabled Process FMEA Knowledge Management Method. *International Jouranl of Intelligent Systems and Applications (IJISA)*, *4*(3), 34-40.

yWorks GmbH. (2015, 01 03). Retrieved from www.yWorks.com: www.yworks.com/en/products_yed_about.html

Zack, M. H. (1999). Managing codified knowledge. *Sloan management review, 40*(4), 45-58.

ABSTRACT

KNOWLEDGE REUSE THROUGH ELECTRONIC KNOWLEDGE REPOSITORIES: AN EMPIRICAL STUDY AND ONTOLOGICAL IMPROVEMENT EFFORT FOR THE MANUFACTURING INDUSTRY

by

PETER CHHIM

December 2015

Advisor: Dr. Ratna Babu Chinnam

Major: Industrial Engineering

Degree: Doctor of Philosophy

Knowledge management adoption is growing, and will continue to grow in no small part because of its recent inclusion into the ISO 9001:2015 quality standard. As organizations look towards ways in which to manage their knowledge, the codification of explicit knowledge through Knowledge Management Systems (KMS) and Electronic Knowledge Repositories (EKRs) will undoubtedly gain interest.

An EKR is a form of KMS that emphasizes the codification and storage of organizational expertise for the purposes of Knowledge Reuse (KRU). Unfortunately, the factors surrounding KRU are not well understood. While previous studies have viewed EKR usage from a narrow perspective, a broader and interconnected view of KRU via EKRs has yet to emerge. As well, while there have been numerous benefits linked to EKRs, there are still issues that limit their utility, particularly in the manufacturing industry where information complexity and geography have made it increasingly difficult to share knowledge.

Hence, this research employed a two pronged approach. First, utilizing a multi-theoretical perspective, a quantitative study of KRU via EKRs was conducted and identified several socio-

technical factors that predicted greater KRU. These factors had not been previously modeled within the context of KRU via EKRs, and hence the findings add to both the theoretical and practical implications of the domain. Additionally, the KRU construct was also tied to a resulting outcome view that was informed by the Expectation Confirmation Model (ECM). Through this view the research quantitatively validated that KRU not only predicted greater performance, but also greater knowledge sharing and continuance of use. This ancillary benefit helps to reinforce the importance of EKRs in that additional gains are manifested along with the core benefit of KRU. Second, the research extends the capability of manufacturing EKRs through the development of a holistic design and process based ontology. While a number of ontological efforts have been pursued in this field, they tend to fall into either broader manufacturing enterprise based efforts, or narrow design and failure mode based efforts. This research presents DPFO, Design and Process Functional Ontology, an interconnected and industry informed approach that helps bridge the gap between design and process knowledge by connecting key concepts from both. Next, the ontology was formalized and tested via Semantic Web tools: RDF, Protégé and SPARQL. The results demonstrate an improved approach to knowledge recall by providing rich and accurate query results. As well, the ability to use standalone and federated queries to effectively cull the complexity of this interconnected domain is an enhancement over traditional keyword and relational database approaches. Additionally, to assist with greater industry adoption, a systematic and constructive approach for developing and operationalizing ontologies is provided. Finally, in the spirit of the program in which this dissertation is presented, rounding out the research effort are broader organizational management recommendations for overall knowledge management. Referencing industry targeted literature and syncing them with findings from this research, several pragmatic and sequentially logical approaches to knowledge management are offered.

AUTOBIOGRAPHICAL STATEMENT

Peter Chhim has worked in the automotive industry for 16 years. During this time he has worked for original equipment manufacturers, as well as tier 1 and 2 suppliers in the fields of process, manufacturing and quality engineering. Through his career has had traveled globally to work with organizational colleagues and support customer needs. He is a member of the 2009 Global Executive Track (GET) PhD program, as well as the American Society for Quality, Automotive Industry Action Group, Original Equipment Supplier Association Warranty Management Council, Golden Key International Honor Society, and Tau Alpha Pi Engineering. Peter is a certified Six Sigma Black Belt through the Michigan Manufacturing Technical Center.

Peter holds a quality control practitioner level II certificate and a diploma in Mechanical Engineering Technology from St. Clair College in Ontario Canada. He also holds a BS in Industrial Engineering Technology and MS in Engineering Technology from Wayne State University. He was born during the Khmer Rouge Regime in Cambodia, but escaped with his family and immigrated to Canada in 1980. He is a Canadian Citizen and Permanent Resident of the United States.