



***A MODEL TO ENHANCE PERFORMANCE OF KNOWLEDGE
MANAGEMENT SYSTEMS THROUGH SEMANTIC
TECHNOLOGIES***

UMAR, ABDULMAJID BABANGIDA

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By

UMAR, ABDULMAJID BABANGIDA

**Thesis Submitted to School of Graduate Studies, Universiti Putra Malaysia, in
Fulfilment of the Requirements for the Degree of Doctor of Philosophy**

December 2019

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DEDICATION

This thesis is dedicated to my beloved parents, my wife (Ruqayya) and my two lovely kids (Khalil and Khadeeja)



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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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December 2019

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Finding and using organizational knowledge is a significant challenge for knowledge management systems (KMS). Unprecedented growth of knowledge and its dispersal across intranet resources, makes it difficult and time-consuming for users to access important knowledge. The importance of getting the right knowledge to the right person and at the right time has been emphasized in relation to KMS performance. However, due to several technical limitations, such timely access to important knowledge is not readily available. Hence, with the advent of semantic web (SW) technologies, several studies argue that these new technologies hold a promise to overcoming the technical limitations of KMSs. Despite these arguments, there is still insufficient understanding and empirical evidence on the adequacy of SW in relation to KMS performance. Thus, the first objective of this study is to identify the key SW features that support timely knowledge access and delivery in KMS. The second objective is to propose an exploration model for the adequacy of SW in relation to the performance of KMS. The third objective is to empirically validate the exploration model.

In the beginning, a comprehensive review of existing SW-based KMS models was performed, to identify and synthesize the SW features influencing KMS performance. Three key dimensions, namely semantic-oriented interface, semantic processing, and semantic-enabled database were identified, and ten important SW features synthesized. Furthermore, four concrete dimensions of KMS performance namely, knowledge quality, searchability, perceived benefit, and user satisfaction were outlined. Accordingly, conceptual model for this study was developed. Next, experts in SW and information systems were used to review and validate the conceptual model. Also, a pilot study involving 28 participants was performed to measure the reliability and validity of the research instrument.

Subsequently, an empirical study was conducted to validate the conceptual model. Academicians in Malaysian public higher institutions were the target population, but the study only used data from those who had experience of using KMS. The data collected was analysed using structural equation modelling (PLS-SEM). Empirical results revealed fitness of the conceptual model to the data, while also demonstrating a significant positive role of SW features: natural language access, refinement capability, navigation capability, personalization, contextualization, knowledge reasoning, knowledge integration, knowledge filter, ontology knowledge model, and thesauri, on the performance of KMS. Conclusively, the SW technologies were found adequate in enabling satisfactory knowledge access and usage in KMS, thereby explaining its performance. Consequently, an adequacy examination model was proposed.

In addition, a prototype which implements the proposed model was developed and named, semantic technology-based knowledge management system (SemTek-KMS). Next, the conduct of an expert validation study to verify the model, revealed that the prototype inhibits SW features from the proposed model that may support adequate exploitation of knowledge resources. A KMS success study was then conducted to evaluate the performance of SemTek-KMS. Result from the study revealed that SemTek-KMS was sufficient in providing adequate quality of knowledge and searchability. Also, the prototype achieved an above average perception of benefit from users, and an overall satisfaction of use.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**MODEL UNTUK MENINGKATKAN PRESTASI SISTEM
PENGURUSAN PENGETAHUAN MELALUI TEKNOLOGI SEMANTIK**

Oleh

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Penemuan dan penggunaan ilmu organisasi adalah satu cabaran yang signifikan untuk sistem pengurusan maklumat atau KMS. Pertumbuhan ilmu pengetahuan yang baru dan penyebarannya merentas sumber-sumber intranet, menjadikan proses pengaksesan pengguna terhadap ilmu yang penting sukar dan memakan masa. Kepentingan mendapatkan ilmu yang tepat kepada orang yang tepat dan pada masa yang tepat telah ditekankan dalam hubungannya dengan prestasi KMS. Namun demikian, mengikut beberapa batasan teknikal, akses kepada ilmu yang penting tidak tersedia. Oleh itu, dengan kehadiran teknologi web semantik (SW), beberapa kajian menghujahkan bahawa teknologi-teknologi baru ini menjanjikan sesuatu untuk menangani batasan-batasan teknikal KMS. Di sebalik hujah-hujah ini, masih terdapat ketidakfahaman dan bukti empirik ke atas kesesuaian SW dalam hubungannya dengan prestasi KMS. Oleh itu, objektif utama kajian ini ialah mengenalpasti fitur-fitur utama SW yang menyokong akses dan penyampaian maklumat yang tepat pada masanya dalam KMS. Objektif kedua ialah untuk mencadangkan satu model eksplorasi untuk menentukan kesesuaian SW dalam hubungannya dengan prestasi KMS. Objektif ketiga ialah untuk mengesahkan secara empirik model eksplorasi tersebut.

Pada mulanya, satu sorotan komprehensif model-model KMS berasaskan SW sedia ada telah dilaksanakan untuk mengenalpasti dan mencirikan fitur-fitur SW yang mempengaruhi prestasi KMS. Tiga dimensi utama, iaitu antara muka berorientasikan semantik, pemprosesan semantik dan pangkalan data bersemantik telah dikenalpasti, dan sepuluh fitur SW yang penting telah diperolehi. Tambahan lagi, empat dimensi konkrit KMS iaitu, kualiti ilmu, kebolehcarian, persepsi faedah, dan kepuasan pengguna telah digariskan. Model konseptual untuk kajian ini telah dibangunkan. Seterusnya, pakar-pakar dalam SW dan sistem maklumat telah digunakan untuk menyorot dan mengesahkan model konseptual tersebut. Seterusnya, satu kajian rintis

melibatkan 28 orang peserta telah dijalankan untuk mengukur kesahan dan kebolehpercayaan instrumen kajian.

Berikutnya, satu kajian empirik telah dijalankan untuk mengesahkan model konseptual berkenaan. Para ilmuwan di institusi pengajian awam di Malaysia adalah populasi sasaran, tetapi kajian hanya menggunakan data dari mereka yang berpengalaman menggunakan KMS. Data yang terkumpul dianalisis menggunakan model persamaan berstruktur atau Structural Equation Modelling (PLS-SEM). Keputusan empirik menunjukkan kesesuaian model konseptual kepada data, juga menunjukkan satu peranan fitur SW yang positif dan signifikan: akses bahasa semulajadi, kemampuan penghalusan, kemampuan navigasi, keperibadian, kontekstualisasi, penaakulan maklumat, integrasi maklumat, saringan maklumat, model pengetahuan ontologi, dan tesauri, ke atas prestasi KMS. Kesimpulannya, teknologi SW didapati sesuai dalam membolehkan akses dan penggunaan maklumat yang memuaskan dalam KMS, seterusnya memperjelaskan prestasinya. Akibatnya, satu model pemeriksaan yang sesuai telah disarankan.

Seterusnya, satu prototaip yang menggunakan model yang dicadangkan telah dibangunkan dan dinamakan Sistem Pengurusan Maklumat Berasaskan Teknologi Semantik atau Semantic Technology-Based Knowledge Management System (SemTek-KMS). Seterusnya, pengendalian kajian pengesahan pakar untuk mengesahkan model itu, menunjukkan bahawa prototaip tersebut menghalang fitur-fitur SW dari model yang dicadangkan yang mungkin menyokong eksploitasi sumber ilmu yang sesuai. Satu kajian kejayaan KMS telah dijalankan untuk menilai prestasi SemTek-KMS. Keputusan kajian menunjukkan bahawa SemTek-KMS dikira wajar dalam menyediakan ilmu dan kebolehcarian yang berkualiti. Seterusnya, prototaip berkenaan telah mencapai persepsi faedah dari pengguna yang berada di atas aras purata, dan kepuasan penggunaan secara keseluruhan.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

AVE	Average Variance Extracted
CB-SEM	Covariance based SEM
CR	Composite Reliability
HTMT	Heterotrait-Monotrait
I-CVI	Item-level Content Validity Index
IPMA	Importance Performance Matrix Analysis
IT	Information Technology
KM	Knowledge Management
KMS	Knowledge Management System
KMS-P	KMS performance
KMSP-KQ	KMS Performance Knowledge Quality
KMSP-PB	KMS Performance Perceived Benefit
KMSP-SE	KMS Performance Searchability
KMSP-US	KMS Performance User Satisfaction
OWL	Web Ontology Language
P2P	Peer-to-Peer
PHI	Public Higher Institutions
PLS	Partial Least Squares
RDF	Resource Description Framework
RDFS	Resource Description Framework Schema
SD	Semantic-enabled Database
SEM	Structural Equation Modelling
SEMTEK-KMS	Semantic Technology-based KMS
SI	Semantic-oriented Interface

SP	Semantic Processing
SPARQL	Simple Protocol and RDF Query Language
SQL	Structured Query Language
SW	Semantic Web
URI	Uniform Resource Identifier
W3C	World Wide Web Consortium
WWW	World Wide Web
XML	Extensible Markup Language



CHAPTER 1

INTRODUCTION

This introductory chapter presents an overview of the entire research study. It starts with a description of the research background and then proceeds with a presentation of the problem statement. Objectives of the study, research questions, scope, and research significance follow respectively. The chapter also describes organization of the thesis to serve as guide to readers on the thesis content. Finally, a brief summary of the Chapter is presented in Section 1.8.

1.1 Research Background

Right from the early days of human inventions, technology has been a fast-moving innovation. Developments ranging from network cables, the internet, world wide web (www), mobile computing, and related fields have directly or indirectly revolutionized businesses, industries, societies, and even transformed lives in so many ways. Similarly, the continuous innovations in technology has been moving hand in hand with the emergence of new problems and challenges, just as any other new solution does. Information technology (IT), one of the most powerful solutions ever invented, has in its name the most substantial issue that remains to be solved. Indeed, the concept of information has been the bedrock of the entire IT paradigm. However, the world today has been transformed to a knowledge-based society (Drucker, 1993). In today's economy, only a few would debate the phrase that 'knowledge is power' (Ale, Chiotti, & Galli, 2008). Organizations and researchers have realized the importance of knowledge as a resource with economic value, which can be utilized to maintain a sustainable competitive advantage. As a consequence, every enterprise (regardless of sector, size, ownership, or specialty) attempts to create value out of the knowledge that is embedded in its employees and processes. Even for enterprises that seem to use little knowledge, effective knowledge management (KM) has become a crucial management mandate. Hence, the development of best practices for managing the complex concept of knowledge is key to riding on today's competitive wave.

Not surprising is the overwhelming attention that has garnered in research on KM. Described as a systematic process of "managing, gathering, organizing, refining, analysing, and disseminating knowledge in all its forms within an organization for certain purposes" (Abdullah, 2008), KM has become a cornerstone for IT research. In recent years, leading research journals and conferences have been dedicated for KM and knowledge management systems (KMS) or related titles. The prevailing aim is mostly to make knowledge accessible and reusable to an enterprise (O'Leary, 1998). Through KMS, it is thought that organizations could make their knowledge resources accessible. Furthermore, potential for innovation and quick adaptation to changing market realities are among the anticipated benefits that fuel research in this direction of IT innovation. However, rather than reports of success stories, most efforts in KMS implementations have not been as successful (McDermott, 1999). At their core,

KMS's have been designed with tools, methods, techniques, and frameworks conceived for information systems. While IT has been successful at dealing with information, knowledge is arguably borderless, difficult to quantify, and inherently multi-dimensional (Nonaka & Takeuchi, 1995), making it difficult for systems to handle. A knowledge seeker for instance submits query to KM system and receive result by mere keyword match. However, keyword match does not take into consideration the meaning or context of the knowledge requested for (Mariel A. Ale, Toledo, Chiotti, & Galli, 2014). Hence, KMS's become relatively inflexible and stifle for finding existing knowledge and subsequent creation of new knowledge (H. Li, Li, Cai, & Liu, 2009). Nevertheless, continuous IT innovation has been one of the crucial factors supporting KM.

Semantic web (SW) technology is one of such IT innovations driving a paradigm shift in today's KM drive (Joo & Lee, 2009). It is a technology that envisages a distributed platform of structured information content, better enabling machines to comprehend documents (Berners-lee, Hendler, & Lassila, 2001). Literature review suggests that several KMS projects are shifting towards some form of SW technology. This implies that SW is perceived important and KMS's could potentially benefit through proper utilization of tools and methods specifically developed to handle knowledge (Davies, Lytras, & Sheth, 2007). For example, ontology, which forms a building block for the SW, provides background information to enrich the description of data. As a result, the contextual information of a specific resource is contained, enabling meaning for web content. Furthermore, certain degree of inter-operability is obtained and sophisticated inferences could be made to provide real knowledge level solutions (Berners-Lee, Hendler, & Lassila, 2001). The on-to-knowledge project which developed a tool suite that efficiently process large numbers of heterogeneous, distributed, and semi-structured documents based on ontology, is one of the early infrastructures built, which facilitated the start of transition from the traditional to the SW based KM systems. A transition that allowed to overcome numerous, and previously challenging problems. In this context, another transition, from the design science based research to the behavioural science perspective may likewise proffer solution for the prevailing problems related to the design, use, and adoption of the SW-based KM systems (Joo & Lee, 2009).

Certainly, beyond the scope of any single study, this research by itself does not enable such a transition. However, it does aspire to contribute towards laying the groundwork for such advancement. Given the background and resources available, this study in line with previous findings (Joo, 2011), presumes that research in the aspect of demand pull in the introduction stage of SW can improve the success of KMS's. Moreover, the perception of benefits of the SW towards solving the limitation factors of KMS's is a push force to accept and adopt the technology (Joo, 2011). Hence, this research first identifies the SW technologies presented in existing SW-based KMS models and frameworks. Through empirical studies, a conceptual model is presented to guide in the understanding of the adequacy SW for the performance of KMS. Finally, the study provides a proof of concept for the conceptualized model and evaluated the model through this prototype concept.

The remainder of this introductory Chapter will provide a discussion on the research problem, research questions to be answered, the objectives this study aims to accomplish, significance of the study, scope that delimits the study, and lastly a summary of the Chapter.

1.2 Problem Statement

One of the main concerns of KM is to understand and resolve issues related to the identification, creation, codification, storage, diffusion, and access to knowledge and to promote learning and innovation (Toledo, Ale, Chiotti, & Galli, 2011). Intranet infrastructure which hosts KMS's play an important role in the effective exploitation of this knowledge. It offers tools to connect individuals with often similar interests to dialogue and exchange tacit knowledge, while also providing interface to stored explicit knowledge. Today, unprecedented growth of organizational knowledge makes it hard to find and use knowledge. Important information is often dispersed across intranet resources, requiring substantial amount of time to browse and read several sources (Che Cob et al., 2016). More so, as users begin to locate similarities and differences among pieces of information, they are faced with a tough: building relationships to create new knowledge (Davies, Fensel, & Harmelen, 2003). Davies, Lytras, & Sheth (2007) explains the excessive human effort required by current KMS's to get the right knowledge to the right person and at the right time.

Indeed, one way of thinking about semantics in KMS is the delivery of knowledge in the right context, i.e. that which can lead to effective action (Antoniou & VanHarmelen, 2004). Motivated by the limitations of current KMS's, application of SW in KMS has garnered substantial research interest. Studies range from the development of infrastructures and architectures, killer applications, tools, business and other social related areas. Most significant interest has been on the development of SW-based KMS frameworks (e.g. Che Cob et al., 2015; Tello-Leal, Rios-Alvarado, & Diaz-Manriquez, 2015;). According to Hevner et al., (2004), studies on architectures refer to design science, which has the characteristics of technology push. However, research in the aspect of demand pull in the stage of introduction of SW has the potential to improve the performance of IT investments (Joo & Lee, 2009). According to Nekvasil and Svátek (2013), most studies that adopt SW technologies are only guided by personal feelings and unclear considerations. There is inadequacy of research on the development of reference models that will help determine the adequacy of semantic approaches given the particular aspect of application (Nekvasil & Svátek, 2013).

Similarly, a study on the adoption of SW from the perspective of technology innovation by Joo (2011) using a grounded theory approach provided following findings:

- Research in the aspect of demand pull for the SW technologies can improve the performance of IT investments.

- Users commonly require demonstrable systems or predicted results to adopt SW technology. However, studies on reference models or killer applications to provide trialability or predicted results are lacking.
- Positive SW technology outlook can significantly increase its adoption.
- Gap between user perception of the SW capabilities and the actual capability the technology offers. This gap of expectation is significantly related to the delayed adoption of the SW technology.

Until recently however, there was limited attempt to address the aforementioned issues. To the best of the researchers knowledge, Che Cob and Abdullah (2017), Che Cob et al. (2015), and Joo and Lee (2009) are the few studies conducted to address some of the issues raised. These studies present features of SW that hold a promise to the performance of KM systems. Nonetheless, they are still not sufficient to provide adequate empirical evidence on the adequacy of SW technologies in relation to the performance of KMS. Accordingly, although it has been suggested that the integration of SW features according to semantic-oriented interface, semantic processing (i.e. meaningful processing mechanisms) and semantic-enabled database would provide better understandability (Lytras and Garcia, 2008), there is a lack of research that examines SW features in this regard.

Hence, this study provides a more holistic approach to examine SW features in KMS performance. The proposed exploration model integrates SW features according to semantic-oriented interface, semantic processing and semantic-enabled database to examine the adequacy of the features in the performance of KMS. Also, established measures of KMS performance (i.e. knowledge quality, searchability, perceived benefit, and user satisfaction) are taken into consideration in the conceptual model.

1.3 Research Questions

The discussions presented in Section 1.2 has clearly indicated a need for research in the aspect of reference models and killer applications to provide perceived benefit and trialability respectively, of SW technologies in KMS. In particular, this study aims to investigate and ascertain prospective adequacy of SW technologies with respect to the performance of KMS. To achieve this, the following questions need to be addressed:

- What are the key features of SW that affect performance in KM systems?
- What is the nature of relationship between the SW features and KMS performance?
- How adequate are SW features in explaining the performance of KM systems?

1.4 Research Objectives

To achieve the main aim of this study and to answer the research questions, the following objectives are set for this research:

- To identify the key features of SW that affect performance in KM systems
- To propose a model to explore the relationship between SW features and KMS performance
- To examine the adequacy of the SW features for the performance of KM systems

1.5 Research Scope

This research is mainly to understand the contribution of SW in the performance of KMS. Since KMS spans across several domains (including health, education, tourism, government, etc.), model validation in this research is specifically conducted in the education domain. Reason been that, education domain produces and disseminates vast amount of knowledge on a regular basis, which makes its management a crucial mandate. Hence, KMS research in this domain becomes very important. Accordingly, academicians as the target population of this study reflects both staff and postgraduate students. This is because, a significant number of postgraduate students happen to be academic staff of institutions, furthering their education. Also, the study population is limited to only public universities in Malaysia. The population size is considered sufficient enough to reflect the entire Malaysian academicians.

1.6 Research Significance

This research provides guidelines to companies interested in or currently implementing SW technologies for KM systems. The study plays a role of bridging the existing gap in the literature regarding SW technologies in KM systems through an empirical study of the relationship between the SW technologies and KMS performance. Indeed, the study is not the first attempt to address these issues. However, it provides a more extensive coverage of the research area. From an academic perspective, as the theory for SW based KMS is still in its infancy, this study is a step forward towards theory building. Moreover, the research through the exploration model for the adequacy of SW features for the performance of KM systems, will provide a guide for future studies on areas where there is potential research outlook.

From practitioner's perspective, organizations seeking to improve their KM IT investments could also benefit from this research. It will help them to understand and perceive the potential adequacy of SW for their KMS investment before making decision to adopt. It can also help in bridging the expectation gap identified by Joo & Lee (2009) between what the users expect the technology could tackle and its actual

potentials. Also, the research offers insights into the critical factors that should be considered in terms of performance for KM systems.

1.7 Definition of Terms

SW-based KMS: In this study, SW-based KMS refers to conceptualizations of KMS that have any element of SW (e.g. ontology) implemented in them.

KMS performance: For clarification purpose, this thesis uses the terms performance, effectiveness and success, interchangeably according to the definitions in existing studies (DeLone & Mclean, 2003; Jennex, 2007).

A goal-centred rather than a system-resource definition of performance is adapted in this study (Hamilton and Chervany, 1981). That is to say that, performance within the scope of this study, entails how well the KMS is able to achieve its desired objectives. Furthermore, social, cultural, and organizational factors of KMS performance are not included in the operationalization of KMS performance for this research.

1.8 Thesis Organization

This thesis contains a total of seven Chapters. In the first Chapter, a summary of the research background is provided. This is followed by the statement of problems, research questions, objectives of the study, research scope, and its significance.

Chapter 2 covers literature studies around the topic of discussion. As introductory part of the chapter, fundamental concepts of KMS which facilitate its effective realization is also briefly presented. Furthermore, a review of existing models and theories in the KMS performance field is discussed as a foundation to understand how best the set objectives can be achieved. Since this research intends to explore the adequacy of SW for KMS performance, literatures around the SW paradigm are also reviewed. Finally, the section highlights some of the research studies that have attempted to investigate or apply semantics into KMS either by providing frameworks or models.

In Chapter 3, the research methodology used in developing the adequacy examination model are discussed. Activities that include how the model was synthesized, verified, validated are the main components of this Chapter. For further validation of the study contributions, a discussion of how a prototype was designed and evaluated is presented at the last sections of this Chapter. Chapter 4 on the other hand presents a detailed discussion of the model development, its components and the hypothesized relationship with KMS performance. In this Chapter, details of past literatures are used to formulate hypothesis, which are subsequently used to empirically examine statistical significance.

Details of the specification, design, and development of a prototype that implements the research model are discussed in Chapter 5. A direct path to achieving objective 3, this Chapter discusses how the prototype enables KM system users to effectively find and access relevant knowledge in the right form and at the right time. Results obtained from the activities leading to the verification, validation, and evaluation of the proposed model are subsequently discussed in Chapter 6. Outcome of the empirical study results from smart-PLS analysis of measurement and structural models is presented. Subsequently, a discussion of the result from our validation of the model through the developed prototype is presented.

Finally, a summary of the entire thesis and concluding remarks on the contributions and limitations of the study is presented. More so, issues that remain open for further investigations in the future, which may further strengthen the contributions from this research and even extend it are also discussed.

1.9 Summary

In this Chapter, the author described the introduction that guides the entire conduct of this research. Beginning with a background of the study, the chapter continues with a discussion of the problems addressed by this research. Furthermore, specific research questions and their accompanying objectives were discussed. Also, the scope delimiting this study was presented, which was followed by a description of the significance of the research study. Finally, readers guide on the organization of this thesis is presented as the closing section of the introductory chapter.

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