UNIVERSITI PUTRA MALAYSIA

KNOWLEDGE MANAGEMENT MODEL FOR PROMOTING GREEN SOFTWARE DEVELOPMENT ADOPTION AMONG SOFTWARE PRACTITIONERS

TEE MCXIN

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By

TEE MCXIN

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

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

KNOWLEDGE MANAGEMENT MODEL FOR PROMOTING GREEN SOFTWARE DEVELOPMENT ADOPTION AMONG SOFTWARE PRACTITIONERS

By

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January 2018

Chairman : Prof. Rusli bin Abdullah, PhD
Faculty : Computer Science and Information Technology

Over the years, use of computing and information technologies (IT) has brought a powerful change in our lives. Although computing and IT improves our daily lives but the technologies have also been contributing to environmental problems. Hence, computing and IT industry is legally, ethically and socially required to "green" their products, applications, services and activities. Environmental sustainability becomes an important issue in the world due to numerous initiatives have been supported by worldwide movement and media coverage. Literature about green software development (Green SD) is increasing since year 2010. However, level of environmental awareness in software development (SD) industry is still low in practice. Currently, there is lack of method in existing literature on promoting green practices (the Green SD knowledge) with the aim of spreading environmental awareness in SD industry. On the other hand, existing literature about knowledge management (KM) implementation in green and sustainable development of various industries has proved that knowledge is the main and valuable asset in order to succeed in achieving environmental sustainability. However, there is lack of research has outlined KM as solution towards managing and sharing of green knowledge efficiently in SD industry. Therefore, this study aims to promote Green SD adoption in SD industry, through exploring KM implementation as facilitation tool to manage and share Green SD knowledge among software practitioners. As a result, a model is proposed which concerns different extents: 1) motivational drivers that motivate software practitioners to adopt Green SD, 2) importance of various green practices in software development life cycle (SDLC), 3) KM in terms of KM process and KM technologies for managing and sharing Green SD knowledge, and 4) perceived outcomes of applying KM in promoting Green SD adoption. Quantitative questionnaire survey was carried out by randomly distributing questionnaire to software practitioners. Data collected was empirically analysed with structural equation modelling partial least squares (SEM-PLS). Analysis shows that ethical motivational driver, KM technologies of artificial intelligence, content creation and management technologies, and e-learning system positively and significantly contribute to promote Green SD adoption through KM facilitation. Besides, the analysis result also proves that all the proposed perceived outcomes: cost-saving, effort-saving and time-saving are positive and significant

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perceived outcomes of applying KM as facilitation tool to promote Green SD adoption. Objectives of this research are achieved by introducing KM models to provide direction and suggestions to the SD industry in addressing environmental sustainability issues. Contribution of this study is presenting a new dimension of green knowledge perspective in SD field of study because this study is the first attempt in research field to fill in existing research gaps by introducing KM in Green SD discipline. While managing and sharing of Green SD knowledge becoming easier, it encourage continuous learning in green practices and develop common understanding on Green SD principle among software practitioners. Moreover, the Green SD knowledge sharing is not only limited to software practitioners, but also is significant in helping to promote understanding among stakeholder and their participation in decision making on environmental issues. So that, in future, the SD industry can help in sustaining computing resources. Major outcome of this study is KM Process-Green SD Implementation Model which will be valuable roadmap for inspiring software practitioners to acquire and share Green SD knowledge at the right time in order to develop greener software products and achieve environmental sustainability in the long run.

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

MODEL PENGURUSAN PENGETAHUAN UNTUK MEMPROMOSI PEMBANGUNAN PERISIAN HIJAU DALAM KALANGAN PENGAMAL PERISIAN

Oleh

TEE MCXIN

Januari 2018

Pengerusi : Prof. Rusli bin Abdullah, PhD
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Selama bertahun-tahun, penggunaan komputer dan teknologi maklumat (*IT*) telah mengakibatkan perubahan yang hebat dalam kehidupan kita. Walaupun *IT* mempertingkatkan kehidupan seharian kita tetapi teknologi juga telah mengakibatkan masalah alam sekitar. Oleh itu, dari segi undang-undang, etika dan sosial, perindustrian *IT* diperlukan untuk "memperhijaukan" produk, aplikasi, perkhidmatan dan aktiviti mereka. Kelestarian alam sekitar menjadi isu penting di dunia kerana pelbagai inisiatif telah disokong oleh gerakan di seluruh dunia dan liputan media. Kajian terdahulu yang mengkaji tentang Pembangunan Perisian Hijau (*Green SD*) semakin meningkat sejak tahun 2010. Walau bagaimanapun, tahap kesedaran terhadap alam sekitar dalam perindustrian pembangunan perisian (*SD*) masih rendah. Masa ini, terdapat kekurangan berkenaan kaedah dalam kajian awal tentang mempromosikan amalan hijau (pengetahuan *Green SD*) dengan tujuan untuk mempromosikan kesedaran terhadap alam sekitar dalam perindustrian *SD*. Selain itu, kajian terdahulu tentang pelaksanaan Pengurusan Pengetahuan (*KM*) di pembangunan lestari dan pengurusan hijau dalam pelbagai perindustrian telah membuktikan pengetahuan ialah aset yang utama dan bernilai untuk berjaya mencapai kelestarian alam sekitar. Walau bagaimanapun, terdapat kekurangan kajian yang menggunakan *KM* sebagai penyelesaian terhadap pengurusan dan perkongsian pengetahuan *Green SD* dengan cekap dalam perindustrian *SD*. Oleh itu, kajian ini bertujuan untuk menggalakkan penerimaan dan penerapan *Green SD* dalam perindustrian *SD*, dengan menggunakan fasilitasi *KM* untuk mengurus dan berkongsi pengetahuan antara pengamal perisian. Model konseptual telah dicadangkan yang mengandungi: 1) motivasi yang menggalakkan pengamal perisian menerima penerapan *Green SD*, 2) kepentingan pelbagai amalan hijau dalam kitaran hayat pembangunan sistem (*SDLC*), 3) *KM* dari segi proses *KM* dan teknologi *KM* untuk mengurus dan berkongsi pengetahuan *Green SD*, dan 4) hasil tanggapan yang menggunakan *KM* untuk menggalakkan penerimaan dan penerapan *Green SD*. Soal selidik kuantitatif telah dilaksanakan dengan mengedarkan soal selidik kepada pengamal perisian secara rawak. Kajian ini telah menggunakan kaedah structural equation modelling partial least squares (*SEM-PLS*) untuk menganalisa data. Analisis menunjukkan motivasi beretika, teknologi *KM* mengenai kecerdasan buatan, teknologi *KM* untuk penciptaan dan pengurusan kandungan, dan sistem e-pembelajaran didapati

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mempunyai kesan dan hubungan positif terhadap penggalakan penerimaan dan penerapan *Green SD* dengan menggunakan fasilitasi *KM*. Selain itu, keputusan analisis juga membuktikan semua hasil tanggapan yang dicadangkan: tanggapan mengenai jimat kos, jimat usaha dan jimat masa mempunyai kesan dan hubungan positif terhadap penggunaan fasilitasi *KM* untuk menggalakkan penerimaan dan penerapan *Green SD*. Objektif penyelidikan ini telah dicapai dengan memperkenalkan model *KM* untuk memberikan arah dan cadangan kepada industri SD dalam menangani isu-isu kelestarian alam sekitar. Sumbangan kajian ini adalah memperkenalkan dimensi baru tentang perspektif pengetahuan hijau dalam bidang pengajian *SD* kerana penyelidikan ini ialah percubaan pertama dalam bidang penyelidikan yang memperkenalkan KM dalam *Green SD*. Selain itu, perkongsian pengetahuan *Green SD* dan peningkatan kesedaran hijau bukan sahaja terhad kepada pengamal perisian, dan juga adalah penting dalam menggalakkan pemahaman antara pelbagai pihak berkepentingan dan penyertaan mereka dalam proses membuat keputusan tentang isu-isu alam-sekitar. Oleh itu, pada masa depan, perindustrian *SD* boleh membantu dalam mengekalkan sumber-sumber pengkomputeran. Hasil utama kajian ini ialah model *KM Process-Green SD* yang holistik dan baharu. Model ini akan menjadi pelan bernilai kepada pengamal perisian untuk mengurus dan berkongsi pengetahuan *Green SD* pada masa yang tepat dengan tujuan membangunkan produk perisian yang mesra alam dan mencapai kelestarian alam sekitar dalam jangka masa yang panjang.

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I certify that a Thesis Examination Committee has met on 5 January 2018 to conduct the final examination of Tee Mcxin on her thesis entitled "Knowledge Management Model for Promoting Green Software Development Adoption among Software Practitioners" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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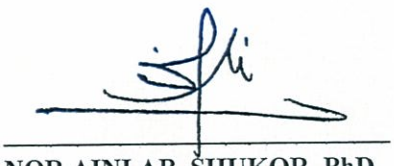

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LIST OF ABBREVIATIONS

CoP	Community of Practice
EKM	Environmental Knowledge Management
GC	Green Computing
Green SD	Green Software Development
Green SDLC	Green Software Development Life Cycle
ICT	Information and Communication Technology
IT	Information Technology
KM	Knowledge Management
KMS	Knowledge Management System
MDGs	Millennium Development Goals
MNSQ	Mean Square
SD	Software Development
SDGs	Sustainable Development Goals
SDLC	Software Development Life Cycle
UN	United Nations
ZSTD	Z-standard

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CHAPTER 1

INTRODUCTION

1.1 Research Background

This chapter clarifies the background of this research and provides initial explanations to it.

1.1.1 Global Call for Green Computing

Environmental sustainability has become an important issue in the world due to numerous initiatives that have been supported by worldwide movement and media coverage that unite people to protect the Earth (Calero & Piattini, 2015; Esfahani et al., 2015). For example, one of the eight Millennium Development Goals that was established by United Nations (UN) at the Millennium Summit, the largest gathering of world leaders in history, was about to endorse environmental sustainability in various industries ("About MDGs", 2006). Moreover, the state-of-the-art UN development agenda that has been introduced by UN is the Sustainable Development Goals (SDGs, a broader sustainability agenda compared to the MDGs), which are strongly demanding for universal effort to work together in protecting the earth ("Sustainable Development Goals", 2015). Generally, environmental sustainability is defined as the effort of improving human welfare and meeting today's needs, in the mean while without compromising the attempt of promoting sustainable use of natural resources and protecting the Earth in the long run (Penzenstadler, 2015).

All parties around the globe have a new important agenda: to face the environmental matters and embrace the environmentally sound practices. Over the years, the use of computing and information technologies (IT) has brought about a powerful change in our lives. Hence, the field of computing and IT should be at the top of the agenda. The use of computing and IT improves our daily lives but the technologies have been contributing to environmental problems such as total electrical power consumption by data centres and computers is gradually increasing (Murugesan, 2008). Computing and IT have been delivering both positive and negative outcomes to the natural environment (Calero & Piattini, 2015). For example, field of computing and IT helps to save the natural environment by harnessing the power of technologies to invent specific hardware or software applications for solving particular environmental problems. In contrast, the field of computing and IT is also responsible for causing environmental troubles, such as high carbon footprint and energy consumption of IT have increased extremely (Du , Pan, & Zuo, 2013). A researcher has forecasted that the total power consumption of the field of computing and IT will be increased by almost 60%, and

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total carbon footprint will be increased by around 70% from year 2007 to year 2020 (Ericsson, 2013).

Existing literature has discovered various motivational drivers that are relevant to organisational decision-making on the issue of adopting green computing (GC) (Mihai et al., 2015; Khor et al., 2015; Tho et al., 2014; Lei & Ngai, 2014; Molla & Cooper, 2014; Yunus et al., 2013; Zhang & Liang, 2012; Chou & Chou, 2012; Jain et al., 2011; Kranz & Picot, 2011). The fast-growing usability of information, communication and greatly complex computations have resulted that high attention on environmental sustainability in the field of computing and IT has been being given by researchers (Afzal et al., 2013). Hence, GC becomes a topic of keen interest and research globally (Agarwal et al., 2015; Saxena, 2015; Negi et al., 2015). For example, International Telecommunication Union, a specialised agency of the UN, has organised a project to introduce standardised environmental guidelines and specific checklist for sustainability requirements in the field of computing and IT (International Telecommunication Union, 2012). Generally, GC is about to support business essential computing demands with minimal possible amount of negative environmental impacts, such as lower power consumption, to finally achieve sustainable computing (Kharchenko et al., 2013). Nowadays, GC is being developed to an essential to adopt environmentally-sustainable solutions (Calero & Piattini, 2015).

1.1.2 Emerging of Green Software Development

Many researchers have focused on GC as a solution for achieving environmental sustainability in the field of computing and IT, such as physical machines, virtualisation and datacentres (Raturi et al., 2015; Naumannet al., 2015; Chauhan & Saxena, 2013; Shenoy & Eeratta, 2011). GC is a broad field of study. In the last few years, researchers who studied on GC have narrowed down their research topics. Hence, the research articles concerning the study of green software development (Green SD) and green software have been starting to emerge (Calero & Piattini, 2015).

There is a difference between the two terms: Green SD and green software. Green SD is adopting and applying cluster of green best practices during software development (SD) process (the software development life cycle, SDLC) so that environmental aspects will be considered by software practitioners who develop different kinds of software products (Calero & Piattini, 2015; Chauhan & Saxena, 2013; Penzenstadler & Femmer, 2013). On the other hand, green software, for example Power Consumption Monitor, is only about to develop specific software application to solve specific environmental issues (Calero & Piattini, 2015; Erdelyi, 2013).

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1.1.3 Promoting Green Software Development: The Existing Endeavours

The increasing attention regarding the topic of Green SD started in year 2010, and it reached a peak in year 2013. The majority of Green SD research papers have concentrated on the study of green software development life cycle (Green SDLC). Pioneers of Green SDLC are Naumann, Kern, Johann, Dick (Naumann et al., 2015; Kern et al., 2015; Kern et al., 2014; Kern et al., 2013; Dick et al., 2013; Johann et al., 2012; Johann et al., 2011), Shenoy and Eeratta (Shenoy & Eeratta, 2011). Shenoy and Eeratta (2011) introduced green practices that need to be adopted in each phase of the SDLC with the purpose of developing environmentally-friendly software products.

In the existing study of Green SD area, green practices about energy efficiency have gained the greatest interest from existing researchers. The researchers have considered that energy efficiency is the objective that strongly needs to be achieved while adopting green practices during SD process (Chauhan & Saxena, 2013; Kocak et al., 2015; Rossi et al, 2014; Penzenstadler et al., 2014; Moshnyaga, 2013). This is due to energy efficiency is one of the most direct measurements to slow down the energy demand growth and to measure whether the software is achieving environmental sustainability. Moreover, this was the first time that one of the topical issues in World Energy Outlook 2015 was concerning the analysis of energy efficiency and the methods of reaching energy efficiency through products' designs (World Energy Outlook, 2015). Hence, energy efficiency has been becoming one of the main goals in Green SD that is being emphasising heavily by the researchers.

The academic studies that are concerning Green SD is growing since year 2010 (Kocak et al., 2015; Beghoura et al., 2015; Kocak et al., 2014; Thiry et al., 2014; Chauhan & Saxena, 2013; Dick et al., 2013; Kern et al., 2013). However, the level of environmental awareness in SD industry is still low in practice (Naumann et al., 2011). It is widely acknowledged that Green SD is still an evolving and vague concept of which software practitioners in the SD industry usually have different perceptions. The software practitioners need to have common understandings on Green SD knowledge with the aim of developing software products in a more environmental manner (Kocak et al., 2015).

In this research context, "Green SD knowledge" is defined as green practices as type of green knowledge that is for applying during SD process with the aim of improving environmental sustainability of software products. Reviewing the existing literature shows that the current body of Green SD knowledge mainly includes green best practices, project experience from senior software practitioners, underpinning technologies to support green, sustainability criteria and metrics that can be implemented by software practitioners during SD process with the purpose of producing environmentally-friendly software products. However, the current issue is software practitioners cannot consistently make green decisions during SD process because there is only limited Green SD knowledge about the ways of developing

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greener software products in the industry (Morisio et al., 2015). They need a method to facilitate flow of Green SD knowledge among them.

1.1.4 KM in Green and Sustainable Development

Nowadays, knowledge becomes the main asset for being successful in combinatorial area of environmental, economic and social sustainable development (Mohamed et al., 2009). Knowledge Management (KM) approaches have been studied by several researchers in green and sustainable development of diverse industries. For example, KM has been applied by researchers in green and sustainable tourism industry (Martinez-Martinez et al., 2015); in renewable energy industry (Lee et al., 2015); in sustainable civil construction industry (Kivits & Furneaux, 2013); in green innovative electronics industry (Wong, 2013); in environment-friendly manufacturing plants industry (Gavronski et al., 2012); in green and sustainable land management industry (Reed, et al., 2011); and in environmental performance of infrastructure industry (Yuan, 2011). The details can refer to Section 2.4.5 of Chapter 2: KM implementation in green and sustainable development. The literature shows that various industries have applied KM successfully in managing environmental knowledge.

Environmental knowledge, or green knowledge, is defined as the type of knowledge that individuals or organisations become aware of and concerned with the environmental matters (Martinez-Martinez et al., 2015). This type of knowledge becomes one of the most significant intangible assets for companies in the competitive market. The existing literature has shown that KM can be applied successfully in capturing, storing and sharing green knowledge efficiently with the aim of decreasing negative environmental impacts. Many organisations have been moving forward with green differentiation strategy in order to develop environment-friendly products which able to create a considerable market (Huang & Shih, 2010). Nowadays, green knowledge becomes a valuable intangible asset that needs to be managed wisely for the contribution of sustaining green competitive advantage in business (Stanovcic et al., 2015; Lee et al., 2015). However, in contrast with the relatively large amount of literature on application of KM in various industries for managing their green knowledge, study of KM implementation as a solution towards managing and sharing of green knowledge (the Green SD knowledge) in the SD industry has not yet been discovered.

1.1.5 KM in Software Development Industry

Main intangible organisational asset in SD industry is the knowledge that resides in the mind of software practitioners who develop software products (Bjornson & Dingsoyr, 2008). This is because SD process is knowledge-intensive process that requires software practitioners to utilise their knowledge (Ozer & Vogel, 2015; Park & Lee, 2014). Hence, it is important to capture knowledge of software practitioners, and then

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share the knowledge efficiently among them to fully utilise the knowledge that lies in their heads. The SD organisations need an action-oriented and collaborative way to transform experiences of seniors software practitioners into actionable knowledge that can be applied during SD process (Fernandez et al., 2015; Jahn, 2012). Therefore, cost and time in developing software will be reduced, quality of software products will be enhanced, and better decisions will be made by software practitioners during the whole SD process (Dingsoyr et al., 2009; Mathiassen & Vogelsang, 2005).

The studies of applying KM approaches in SD industry have been explored by several researchers. For example, study of relationship between knowledge sharing and performance in SD (Ozer & Vogel, 2015; Park & Lee, 2014; Chen, Li, Clark, & Dietrich, 2013; Ghobadi & D'Ambra, 2013), knowledge transfer effectiveness in global SD (Gopal et al., 2015), application of KM techniques in managing risk factors for SD projects (Neves et al., 2014), KM framework for software maintenance environment (Mohd Nor, 2012), and KM metrics in SD companies (Goldoni & Oliveira, 2010). The details can be referred to Section 2.4.4 of Chapter 2: KM implementation in SD environment. The previous researchers have discovered about successful KM application in SD industry. The literature shows that process of collecting knowledge and then storing the knowledge in database can suggest improvement to the new SD projects in the future. However, the existing KM models from current literature are not capable of providing accurate direction and suggestions to the SD industry in addressing environmental issues. The SD organisations have not yet positively and fully embraced the environmental ideas and implement them in SD projects.

1.2 Problem Statement

GC is a broad field of study. Green SD is one of the specific and in-depth disciplines in study and practice of GC. Green best practices and metrics of Green SD have been introduced by researchers in the existing literature (Shenoy & Eeratta, 2011) which highlight various green practices that can be implemented during SD process. However, level of awareness on environmental sustainability among software practitioners in the SD industry is still low in practice (Naumann et al., 2011). Besides, software practitioners cannot consistently make green decisions because there is only limited green knowledge on design, implement and maintain greener software products in the SD industry (Morisio et al., 2015). The software practitioners should have common understanding on green knowledge in order to develop software products in an environmental manner (Kocak et al., 2015). There is a need to collect empirical data from the software practitioners in the SD industry with the purpose of discovering their perspective towards the various green practices suggested by academic researchers, and also to manage and share the green practices efficiently among the software practitioners. So that they can have common understanding on what is Green SD about and what are the green practices that should be performed during SD process.

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On the other hand, existing literature shows that there are several research papers have proposed KM implementation in SD industry (Ozer & Vogel, 2015; Gopal et al., 2015; Neves et al., 2014; Park & Lee, 2014; Chen et al., 2013; Ghobadi & D'Ambra, 2013; Mohd Nor, 2012; Jahn, 2012; Garcia et al., 2011). These existing studies have supported that KM can be implemented successfully in SD industry. Moreover, existing works about KM implementation in green and sustainable development of various industries have proved that knowledge is the main and valuable asset in order to succeed in environmental and sustainable development (Martinez-Martinez et al., 2015; Stanovcic et al., 2015; Lee et al., 2015; Reed et al., 2014; Kivits & Furneaux, 2013; Wong, 2013; Gavronski et al., 2012; Reed, et al., 2011; Yuan, 2011; Huang & Shih, 2010). To apply KM as a successful tool for managing and sharing knowledge, people are the most important component because sharing of tacit knowledge that lies in the mind of people is essential to the success of KM implementation (Uriarte, 2008). Hence, the green knowledge in SD industry should not only reside in the mind of experts, without sharing to the software practitioners who are directly involved in SD process.

After thorough search of the relevant literature, the main problem found in existing academic literature is: existing KM frameworks and models are not capable of providing direction and suggestions to the SD industry in addressing environmental sustainability issues. To the best of author's knowledge, there is lack of research that has outlined KM as a solution in a schematic and holistic view. Therefore, such problem motivates author of this research to explore KM implementation as facilitation tool to promote Green SD adoption in SD industry, by managing and sharing Green SD knowledge efficiently among software practitioners.

1.3 Research Questions

In order to solve the problem statement and research gaps, the main research question is: How to promote Green SD adoption among software practitioners through KM facilitation as a tool? Four research questions are raised to break down the big research question into achievable objectives.

Q1: What are the motivational drivers that motivate software practitioners to adopt Green SD through KM facilitation?

Q2: What are the important green practices in different phases of Green SDLC that should be focused when promoting Green SD adoption?

Q3: How can KM manage and share Green SD knowledge (the green practices in SD process) for promoting Green SD adoption among software practitioners in SD industry?

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Q4: How outcomes are achieved in KM towards a new contribution in managing and sharing Green SD knowledge?

1.4 Research Objectives

In order to answer the research questions raised earlier for this study, four research objectives are established.

1. To analyse motivational drivers that motivate software practitioners to adopt Green SD through KM facilitation.

As mentioned by Mohd Nor (2012), one of the main pillars in KM is people. Besides, Uriarte (2008) stated that people are the most important component. Therefore, motivational drivers should be treated as significant KM software influences on people. Hence, this research will study on current motivations of software practitioners to adopt Green SD in SD industry.

2. To discover various green practices in different phases of Green SDLC and to study importance level of the green practices while promoting Green SD adoption to software practitioners.

Selection of appropriate KM depends heavily on the nature of knowledge itself (Yuan, 2011). Hence, a good understanding of the existing body of Green SD knowledge is significant to this study. In this research, Green SD knowledge is green practices in SD process. Thus, this research will first extract various green practices from existing literature, then study on importance level of the green practices according to different phases of Green SDLC. This objective can promote phase-by-phase green best practices to the software practitioners.

3. To propose KM process and technologies to manage and share Green SD knowledge (the green practices in SD process), with the aim of promoting Green SD adoption among software practitioners.

Research of Mohd Nor (2012) showed that three main pillars of KM: people, process and technology are important components of KM-related models in SD industry. Hence, this objective will study on applying KM process and KM technologies to manage and share green practices among software practitioners. This objective can respond to the problem statement by applying KM in SD industry as a solution to provide accurate direction and suggestions to the SD industry in addressing environmental sustainability issues.

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4. To study outcomes of applying KM to promote Green SD adoption among software practitioners.

There is an axiom that the value of knowledge does not lay in the knowledge itself, the real value lies in the potential of that knowledge can contribute (Yuan, 2011). Hence, this research objective will study on perceived outcomes of applying KM in managing and sharing Green SD knowledge with the aim promoting Green SD adoption among software practitioners in the SD industry.

1.5 Significance of the Study

There is a rising concern that KM is applied in green and sustainable development of different industries. The current literature shows that knowledge is the main intangible asset in order to succeed in the combinatorial area of environmental, economic and social sustainable development (Huang & Shih, 2010; Yuan, 2011; Gavronski et al., 2012; Wong, 2013; Reed et al., 2014; Stanovcic et al., 2015). Thus, this study is a response for further research that specifically explores about applying KM in SD industry. The aim of this study is promoting Green SD adoption in order to provide accurate direction and suggestions to the SD industry in addressing environmental sustainability issues. This study can fill in the current research gaps by introducing KM in SD industry and in Green SD discipline.

This study postulates a model to explore KM implementation as facilitation tool to promote Green SD adoption in SD industry, by managing and sharing Green SD knowledge efficiently among software practitioners. The proposed model is seen as a possible solution which can provide a platform for all the software practitioners to share green best practices and experiences, to inspire new environmental ideas, and to promote environmental awareness in the SD community of practice (CoP). As different issues about environmental sustainability in SD industry should be faced from a knowledge perspective, the results of this study will provide SD organisations and software practitioners with a holistic introduction for understanding KM, and applicable strategies for its facilitation. It is hoped that these efforts can help the SD organisations to develop KM initiatives for managing Green SD knowledge in order to promote environmental sustainability uptake and implementation during SD process, with the aim of enhancing the body of Green SD knowledge, and delivering positive outcomes. This will eventually accelerate the SD industry's move towards environmental sustainability. Thus, it is believed that this study will stimulate not only the interested academic researchers, but also SD industry and software practitioners to join a continuing evolution on KM facilitation in this important Green SD discipline.

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1.6 Scope of the Study

Firstly, the search of existing literature in this study is only carried out on three major sections: KM, SD, and GC, with the aim of finding current research gaps and problems. Figure 1.1 illustrates the area of concern of this study.

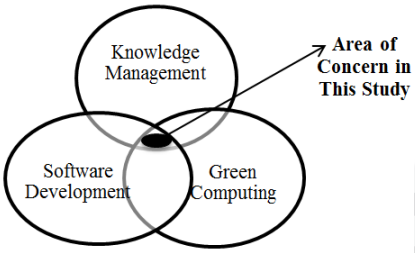

Figure 1.1: Area of Concern in This Study

Secondly, GC is a broad topic of study in the field of computing and IT. Therefore, certain limit to the area of study should be set. After conducting literature review, the author decides to narrow down the scope of research in order to avoid difficulty of adequately addressing the problem in the space and time allowed. As shown in Figure 1.2, this research narrows down its scope to only study on the Green SD discipline. All the terms in Figure 1.2 and the scope of the term "Green SD" will be explained in Section 2.2: Figure 2.2 comprehensively.

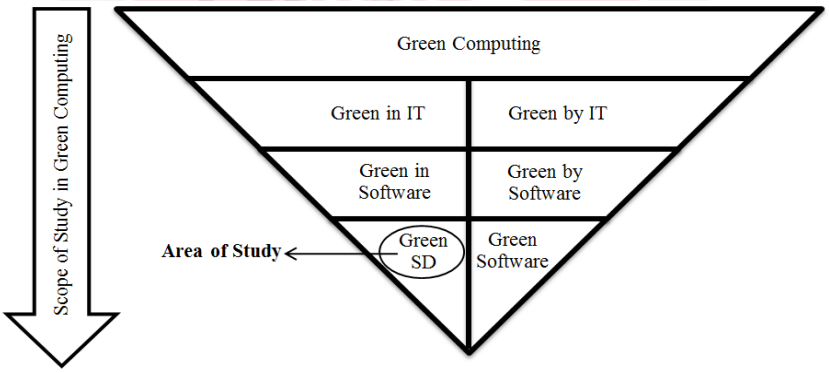

Figure 1.2: Area of Study in GC Field

As shown in Figure 1.3, sustainability of software consists of three dimensions: environmental, economic and social dimensions (Chitchyan et al., 2015). The literature review conducted in this study reveals that except the research paper of Chitchyan et al. (2015), all the other researchers still are focusing on environmental sustainability of software. This is the current trend. Hence, this research narrows down its scope to only

focus on the environmental sustainability (it is also called as the green dimension). Based on the current literature, environmental sustainability is defined as effort to improve human welfare and satisfy current human's needs without compromising the future needs, by protecting the natural resources and the environment on a long-term basic (Penzenstadler, 2015).

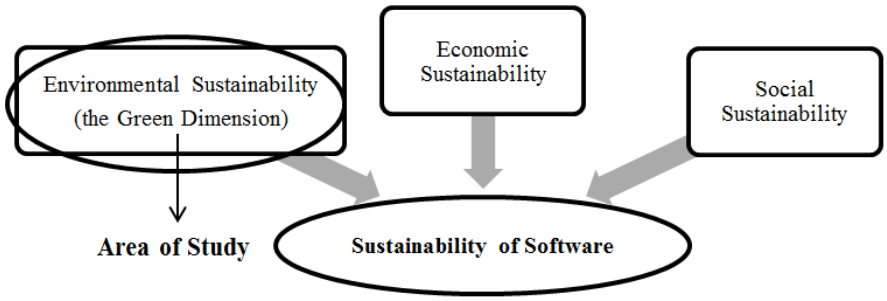

Figure 1.3: Area of Study in Sustainability of Software

In short, this study discusses the knowledge, KM related initiatives, and relevant issues in regards to environmental sustainability that limit the research scope within the Green SD discipline.

1.7 Outline of the Thesis

This study consists of seven chapters. A brief summary of each chapter is described below.

Chapter 1 includes introductory section that states the background and direction of this research, which comprises of a brief description of research background, problem statement, research questions, research objectives, significance of the study and scope of the study.

Chapter 2 consists of review of literature in three diverse main fields: GC, SD and KM. Then, existing frameworks, models, main concepts and approaches are highlighted. Research gaps that are found in the existing literature are clarified in detail. A link between KM and Green SD is presented. Lastly in this chapter, this research will propose an initial model and research hypotheses.

Chapter 3 explains research methodology in detail. This study consists of four main phases. Phase I of the study is discovering current research gaps by studying existing literature. Then, an initial model and hypotheses are proposed. Phase II consists of

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expert verification, pilot study, and data analysis of pilot study with the objective of constructing research instrument of this study. Next, Phase III of this study includes data collection and data analysis process with the aim of validating the proposed model. Lastly, Phase IV is about the process of designing, developing, and evaluating a proof-of concept prototype.

Chapter 4 presents results of data analysis of pilot study, with the aim of constructing research instrument (the questionnaire set) of this research. The research instrument will be used as a tool to collect data for quantitative survey of this study. Then, the process of data collection and analysis will be explained.

Chapter 5 illuminates design and specifications of a proof-of-concept prototype. The proof-of-concept prototype allows the author of this study to show the proposed model actually works and functions as intended. The prototype acts as a show-and-tell tool by providing a basic functioning model that the audiences can understand.

Chapter 6 discusses data analysis and findings of the quantitative survey for model validation. Then, based on results of the empirical analysis, this chapter will discuss the newly proposed model of this study in detail, by presenting significant components of the proposed model in managing and sharing Green SD knowledge.

Chapter 7 summarises this research, and then presents the research contributions from theoretical and practical perspectives, research limitations, recommendations for future research and lastly conclusion of this research.

1.8 Summary

This chapter delivers an overview of this research. The chapter begins with research background on: GC, Green SD, KM implementation in green and sustainable development of various industries, and KM implementation in SD industry. Then, problem statement is identified, which formulates research questions and research objectives. After that, this chapter is followed by significance of the study, scope of the study and outline of the thesis. To conclude, this research is aimed at developing a new model with KM facilitation for managing and sharing Green SD knowledge among software practitioners. The ultimate goal is promoting the uptake of environmental sustainability principles in the real SD projects through the management of Green SD knowledge in the SD industry.

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