Toward Developing Green Software Development Model in Managing Knowledge of IT Practitioners for Sustaining Future Generation

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ABSTRACT
Global awareness of sustainability issues lead to researchers and organizations concentrate on applying green computing as solution to achieve sustainability. However, various previous studies mainly focus on hardware solution rather than software. Hence, there is lacking of model in discussing green software development (GSD). This paper suggests that knowledge about activities, practices and policies of GSD should be gathered from numerous IT experts, researchers and practitioners and stores the collected knowledge in one system. Hence, techniques of knowledge management (KM) is applying and emphasizing on capturing knowledge of GSD and share the knowledge among all IT practitioners, who are programmers, system analysts, software engineers, software maintenance workers and network administrators. Therefore, with the help of KM, the green knowledge can transform into actionable knowledge, which able to apply in developing software, and finally produce greener software product. Most importantly, Power consumption and carbon footprint can be minimized throughout GSD life cycle. In the end, goal of sustaining future generation can be achieved because the future generation able to have their needs met. In this paper, a GSD model will be proposed for enabling KM in facilitating the ultimate goal of sustainability to be achieved.

Keywords: Green software Development, Knowledge Management, Sustainability, IT Practitioner, Green Technology.

I INTRODUCTION
Due to global environmental awareness, competitive awareness and industry initiatives, a large number of organizations hope for achieving sustainability in social, environment and economic aspects (Murugesan, 2008). Many researches focus on green computing as a solution for energy-saving on physical machines, virtualization and datacenters. However, previous researches and organizations didn’t pay much attention from software development perspective (Chauhan & Saxena, 2013; Naumann et al., 2011; Shenoy & Eeratta, 2011). For example, Greenpeace is introducing methods to control energy used in datacenters (Greenpeace, 2010). However, the same approach may not be suitable to apply to software perspective. Besides, the growing usability of information, communication, application developments and greatly complex computations result that energy consumed in computation, storage and software should be paid high concentration (Afzal et al., 2013). Hence, there is a need to explore more opportunities about how to minimize power consumption and carbon footprint while developing software in order to achieve sustainability in the long run.

There are at least two ways to achieve sustainability in IT industry, first, by using lesser energy and resources; and second, by constructing the processes to become more sustainable (Kocak, 2013). In order to achieve these, this paper will suggest that knowledge about activities, practices and policies of GSD should be collected from various IT experts, researchers and practitioners. This is due to different green knowledge about GSD is retained at different IT experts, researchers or practitioners. The problem is the difficulty of sharing all the green knowledge within IT environment. Hence, this research will suggest gathering and storing of green knowledge into one system. Techniques of KM will be implemented to achieve this purpose in assembling and storing the green knowledge of GSD in an appropriate place and format, and then the knowledge can be accessed at the right time, in the right place and to the right IT person (Lakulu et al., 2010; Abdullah R., 2008). So that, while all the IT-related persons can access to the green knowledge and apply them into the software development life cycle, then minimization of power consumption and carbon footprint can be achieved. A greener software product can be developed, which the goal of sustaining future generation can be accomplished, without compromising their own needs. At the final part of this paper, a GSD model for sustaining the future generation is proposed.
II LITERATURE REVIEW

A. Knowledge Management

Knowledge management (KM) can be defined as processes involved in assembling and storing knowledge in an appropriate place and format, and then how the knowledge could be accessed at the right time, in the right place and to the right person (Lakulu et al., 2010; Abdullah R., 2008). IT practitioners consist of programmers, system analyst, software engineer, software maintainers and network administrator. Community of Practice (CoP) had been termed as a group of individuals who deepen their knowledge and expertise in a specific field by sharing and interacting on regular basic (Wenger, 1998). Therefore, in this paper, IT CoP shares different kind of knowledge (Mohd Nor et al., 2009), such as: domain knowledge (knowledge of products and processes), knowledge on source of knowledge (where is the knowledge resides), managerial knowledge (task and project tracking and management, resource and input management), organizational knowledge (roles of different IT practitioners); and technical knowledge (system analysis, requirement analysis, development tools etc.).

B. Green Software Development

Four dimensions: social, environment, economic and technical, should be measured in analyzing sustainability of software (Penzenstadler & Femmer, 2013). According to Chauhan and Saxena (2013), and Penzenstadler and Femmer (2013), concept of GSD life cycle should be propagated in the early stage to create environmental awareness. Therefore, energy consumed, resource waste and pollution can be minimized from the beginning of GSD life cycle to the end.

There are five phases in software development life cycle (Requirements, Design, Implementation, Testing, and Maintenance). However, from Green perspective, several important steps need to be added into the process of life cycle. In the Requirement phase, sustainability should be added as one of the nonfunctional requirements(Chauhan & Saxena, 2013; Afzal et al., 2013). Besides, Design phase should include energy consumption issue, such as to reduce highly dependent modules which could result in high energy consumption (Chauhan & Saxena, 2013). Moreover, due to increasing popularity of smart gadgets (with limited battery power), GUI design should optimize user interfaces in order to save energy (Vallerio et al., 2006). Data structure and algorithms design should also prevent redundancy and uncontrolled dataflow (Potlapally et al., 2003). In Implementation phase, Kocak (2013) suggested that efficient code can reduce cost overheads and energy depletion. Afzal et al. (2013) recommended that programming language used can affect energy consumption, which particular of the languages will effectively practice multithreading and garbage collection methods in CPU and memory. Hence, this issue should be thought wisely. On the other hand, testing procedure should be well-organized, which includes scope, objectives, approach, number of people and amount of equipment assigned for the planning of energy consumption testing. Lastly, Chauhan and Saxena (2013) suggested that software maintenance unit and users should keep an eye on carbon footprint of the software patches and fixes from time to time.

On the other hand, Shenoy and Eeratta (2011) proposed a model which to improve effectiveness of the phases of software development lifecycle by giving recommendations about green activities and practices that can be implemented in the lifecycle. Moreover, in the model proposed by Shenoy and Eeratta (2011), environment-friendly infrastructure such as meeting rooms, hardware, power equipment etc., is crucial in developing software. Besides, a number of quality processes and standards which targeted to achieve sustainability need to be focused in the software development lifecycle.

C. Relationship of Knowledge Management and Green Software Development

Environmental sustainability, global warming and pollution grow to be a crucial global topic which concerns everyone and also the future generation, so that there is a need to expect efforts from all sectors of society, including the information professionals (Jain P., 2008). In the structure of this research, knowledge means information on GSD. From the sustainability perspective, KM can be defined as a practice to capture, assemble, share and apply both tacit and explicit knowledge about GSD for the purpose of reduction of energy consumed, resource waste, global warming and pollution so that can achieve environmental sustainability in long-term.

Hence, in this paper, the scenario of GSD, KM and the relationship between them is emphasizing on capturing the related knowledge of GSD and then sharing the findings to IT practitioners so that they can transforming the green knowledge into actionable knowledge.

D. Actionable Knowledge

Knowledge of GSD that retains in certain IT experts or researchers should be transformed into actionable knowledge through KM techniques so that the green knowledge can share among all IT persons. Actionable knowledge has been defined as knowledge that needs to be connected in the real world (Argyris, 1996). It means to gather huge amount of information and transform the
information into knowledge that can be applied in creating effective solution to answer certain issue (Narducci, 2002). As suggested by Narducci (2002), knowledge will only become actionable knowledge while the whole organization agrees and understands that what the knowledge is by having collaboration. Besides, researches prove that knowledge must become “actionable” and answer the right questions in order to have positive effect (Posner, 2009). Hence, in this research, knowledge of GSD will become “actionable” in the IT environment while the knowledge is been shared and collaborated among IT practitioners. For example, in the design phase of GSD, researchers know that if designing highly dependent modules will lead to high energy consumption. This is the knowledge of GSD that already been knew by certain people, but it only becomes actionable knowledge if the technique is shared among all IT practitioners and they agree with it. However, problem that occurs between experts or researchers and practitioners is: experts and researchers may argue that practical applications are not their responsibility (Cummings & Jones, 2004). This problem causes the IT practitioners face difficulty in turning knowledge of experts and researchers to actionable knowledge. Hence, IT practitioners need an action-oriented and collaborative way to transform existing findings of experts and researchers into more “actionable” to the real world.

Therefore, at first, this research will identify all the techniques, methods, practices of GSD life cycle suggested by current researchers. Then, all the knowledge of GSD will be gathered and stored through KM system. So that, IT practitioners can retrieve the knowledge from the system as needed, and apply them in the real world. Hence, the green knowledge becomes “actionable” while they apply the green knowledge in process of developing a software, which will help to achieve the goal of developing green software that able to reduce the use of scarce resources, carbon footprint and energy consumption. In the long run can sustain the future generation, without compromising the ability of the future generation to meet their own needs.

III METHODOLOGY
To develop the GSD Model for enabling KM in facilitating the ultimate goal of sustainability to be achieved among IT practitioners, there are involving steps as shown as below which are studying on existing papers and recognition of the state of practice:

a) Study and evaluate literature in the scope of green computing. In order to decide scope of this research, existing papers from different green computing perspective had been read. Table 1 shows the citation of literatures on hardware of green computing, green cloud computing and GSD from year 2013 that have been studied:

<table>
<thead>
<tr>
<th>Component of Green Computing</th>
<th>Source</th>
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<tbody>
<tr>
<td>Hardware of Green Computing</td>
<td>(Abbasi et al., 2013)</td>
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<td></td>
<td>(Ahangama &amp; Gunawardana, 2013)</td>
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<td></td>
<td>(Bezakova, 2013)</td>
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<td>(Ferrero, et al., 2013)</td>
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<td>(Kharchenko &amp; Gorbenko, 2013)</td>
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<td>(Li &amp; Lin, 2013)</td>
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<td>(Mittal &amp; Zhang, 2013)</td>
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<td>(Gupta, et al., 2014)</td>
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<td>(Jones, et al., 2013)</td>
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<td>(Sehdev &amp; Kumar, 2014)</td>
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<td>(Wang &amp; Khan, 2013)</td>
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<td>(Venkatraman &amp; Cain, 2014)</td>
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<td>(Abdullah A., 2014)</td>
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<td>(Atrey et al., 2013)</td>
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<td>(Bruno et al., 2013)</td>
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<td>(Chowdhury et al., 2013)</td>
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<td>(Gong et al., 2013)</td>
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<td>(Hu &amp; Tham, 2013)</td>
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<td>(Jain et al., 2013)</td>
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<td>(Jing et al., 2013)</td>
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<td>(Kaur, Kaur, &amp; Singh, 2013)</td>
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<td>(Afzal et al., 2013)</td>
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<td>(Chauhan &amp; Saxena, 2013)</td>
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<td>(Kocak, 2013)</td>
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<td>(Penzenstadler &amp; Femmer, 2013)</td>
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<td></td>
<td>(Potlapally et al., 2003)</td>
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<tr>
<td>Green Cloud Computing</td>
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<td>Green Software Development</td>
<td>b) Conduct preliminary survey by studying existing papers in software development related to green technology,</td>
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<td></td>
<td>c) Analyse and propose GSD Model (Details will be explained in next section).</td>
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IV PROPOSED MODEL
As preliminary result of this research, the proposed model can be formulated as shown in Figure 1:

![Proposed Model Diagram](image)

Based on the proposed model, the top layer is green computing, which includes study and practice of IT-related architecture, hardware, software, networks, systems and processes. Green computing is applied to govern environmental carbon footprint and to minimize power consumption by using computing resources effectively and efficiently with minimal negative effect to the environment, in the mean while without compromising economic productivity and social responsibility in the long run.

However, in the overall green computing philosophy, this paper will only focus deeply on the GSD. There are five key phases of GSD life cycle: Requirements, Design, Implementation, Testing and Maintenance. Improvement on the activities, policies and practices of every phase will be discussed to minimize harmful influence on the environment. Concept of energy efficiency and minimization of carbon footprint should be introduced in the early stage of GSD life cycle. Therefore, future work of the research will mainly focus on constructing the detailed parts of these five phases of the life cycle. Moreover, as shown in Figure 1, power consumption and carbon footprint are the performance measurements that the research will apply in future in order to check the correctness of the proposed suggestions about the improved activities, policies and practices of the life cycle.

KM system needs to be included to manage knowledge of GSD effectively in supporting the process of capturing, storing and disseminating knowledge. The KM system will make sure that knowledge of GSD could be accessed at the right time, in the right place and to the IT practitioners while the specific knowledge in needs. KM system will help to build the IT community into a learning organization by adapting green practices and knowledge into software development process. The system can facilitate a smooth flow of GSD lifecycle and achieve sustainability in the long run.

The proposed model has been validated by seven experts. The experts are: 1 associate professor, who is an expert in KM and software engineering; 2 senior lecturers, who is an expert in software engineering, an another senior lecturer is an expert in KM and information system; 2 senior programmers, who work in private sector of software development industry for more than six years; and 2 programmers, who work in private sector of software development industry for more than two years. All of the experts are knowledgeable in software development, and they are aware about the importance of green computing and also GSD.

V DISCUSSION

According to Table 1 as shown in chapter III, percentage of existing literature on hardware of green computing, green cloud computing and GSD from year 2013 was calculated. As shown in Figure 2, mainly of the existing papers (48%) concentrated on hardware of green computing, such as green data center, green resource management, green chips and devices, solar power equipment, green PCs, laptops and servers, electronic waste etc. On the other hand, there were 33% of the existing literatures from year 2013 focused on green cloud computing, which become a popular trend in these few years. However, among the existing literatures that had been studies, there are only 19% of the studies from year 2013 focused on GSD. Hence, focus to pay on GSD is strongly needed since we can see the emerging trend on it.

Table 2 presents citation of existing literatures about the perceivedness of advantages of green software which based on papers from year 2008 to year 2013.

<table>
<thead>
<tr>
<th>Perceived Advantage of Green Software</th>
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<tr>
<td>Competitive Advantage</td>
<td>(Kocak et al., 2013)</td>
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<td>(Xuan et al., 2008)</td>
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<td></td>
<td>(Zhou et al., 2008)</td>
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<td>Economic Efficiency</td>
<td>(Albertao et al., 2010)</td>
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<td></td>
<td>(Naumann et al., 2011)</td>
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<td>(Spreng, 2013)</td>
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<td>Energy-Saving</td>
<td>(Afzal et al., 2013)</td>
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Bringing a sustainable environment for the future

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http://www.kmice.cms.net.my/

(Capra et al., 2012)
(Chauhan & Saxena, 2013)
(Kocak, 2013)
(Shenoy & Eeratta, 2011)
(Spreng, 2013)
(Chauhan & Saxena, 2013)
(Karanukaran & Rao, 2013)
(Malmodin et al., 2013)
(Naumann et al., 2011)
(Shenoy & Eeratta, 2011)

Minimization of Carbon Footprint

<table>
<thead>
<tr>
<th>Competitive Advantage</th>
<th>Economic Efficiency</th>
<th>Energy Saving</th>
<th>Minimization of Carbon Footprint</th>
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<td>17.65</td>
<td>17.65</td>
<td>35.29</td>
<td>29.41</td>
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Figure 3. Percentage of Perceived Advantage of Green Software.

According to Table 2 as shown as above, percentage of perceived advantage of green software was calculated. Based on Figure 3, the highest perceived advantage of green software, which is 35.29%, is to save energy. Energy-saving is an immediate advantage. By exercising the use of energy-saving devices and hardware, providing power-down capabilities and minimizing installation size in developing software could save a lot of energy.

Besides, perceived advantage of minimization of carbon footprint is the second highest, which is 29.41%. Green software could encourage reuse related components, and then able to ensure low emission and minimize ecological carbon footprint, bringing a sustainable environment for the future generation.

However, perceived advantages of both competitive advantage and economic efficiency are ranked as the lowest (17.65%) within the overall perceived advantages. This circumstance happened because of the competitive advantage and economic efficiency only is able to achieve indirectly and in the long run.

VI CONCLUSION

As a result of the preliminary survey, this research tries to propose a model in managing knowledge of GSD effectively. The model emphasizes importance of adapting green knowledge in developing greener software, and helps in sharing the green knowledge among IT practitioners, so that an environment-friendly software product can be developed effectively. The KM system can facilitate potential to increase sustainability for all phases of the GSD life cycle. The model will also bring intangible benefits to IT CoP and as well as the organizations, for example encourages corporate social responsibility in the aspect of protecting the environment, achieves energy and resource efficiency, minimize carbon footprint and also increase economic efficiency and competitive advantages indirectly in the long run.

Future work of the research is to construct detailed parts of the GSD model, especially main focus is on the five phases of the GSD lifecycle. Then, verification of the model will be carried out in quantitative method. Power consumption and carbon footprint will be used to measure the correctness of the proposed model. Data will be collected and analyzed to ensure reliability and validity of the model.

REFERENCES


