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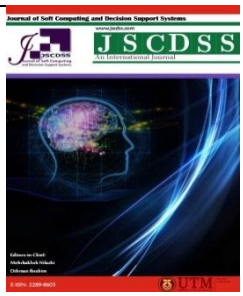

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# Green IS for Sustainable Decision Making in Software Management

Bokolo Anthony Jnr [a,*], Mazlina Abdul Majid [a]
[a] Faculty of Computer Systems and Software Engineering
Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300 Gambang, Kuantan, Pahang, Malaysia

*** Corresponding author email address**: bkanjr@gmail.com

**Abstract**

Software industries, society and government are becoming increasingly concerned about the impact of the increasing use of IT infrastructure on the environment, especially in terms of energy efficiency, emission reduction and toxic waste. There are few models or frameworks that can assist software practitioners in making decision on how to integrate sustainable green practices in software management process. Thus this paper contributes and studies on the use of information systems to support sustainability in software industries known as "Green IS" and provides a preliminary insight into the utilization and integration of sustainability in software management process as well as the variables that influence eco-environmental practices by proposing a model that will assist decision making for sustainable software management process. Thus contributions of Green Information Systems (IS) to the objectives of software management process are examined by exploring secondary data from literature. Findings from this paper show how the proposed model contributes to sustainable software management process. The proposed model provides software developer, software managers, and other software practitioners with new insights and enables a more systematic application of sustainable practices in software processes.

Keywords: Green IS, Sustainability, Software management, Environment, Decision making

## 1. Introduction

The limitation of integrating Green information systems into software management to create a sustainable decision making in software process is a current issue. The memo of sustainable development was placed on the global agenda in 1987 and has still not been systematically addressed by software and corporate sector. Despite growing concern over climate change and other sustainability issues (Chris et al., 2014). Sustainability or Eco-Sustainable development implies a long term vision, which does not compromise the ability of future generations to meet their needs. Green Information System is a current recognized domain in Information Systems research which has been the topic of academicians, researchers and practitioners since 2007. However, researchers in this field have addressed the issues related to environmental sustainability and the application of IS in software processes (Esfahani et al., 2015c).

According to Helen et al. (2012) information systems discipline can have a central role in creating an ecologically sustainable society because of the field's five decades of experience in building, designing, deploying, evaluating, managing and studying IS to resolve complex problems. Therefore, there has been major concern regarding environmental sustainability issues. Besides, software industries are under pressure from government, environmental organisation and shareholders to improve their environmental sustainability activities. Green Information Systems in software process is aimed at mitigating software development's impact on the natural environment, in which these strategies can include changes to software practitioner's, processes, products and governance structure such as reducing energy consumption and waste generation, using organic sustainable resources, and implementing an ecological management system (Esfahani et al., 2015b).

Thus, Green Information Systems (IS) is associated with social, economic and environmental aspect of software process and has much to contribute to sustainable outcomes in the face of climate change and other environmental challenges. Information and Communications Technologies (ICT) can be seen as major polluters through the energy used over the life cycle of software development process, ICT devices and through e-waste (Bokolo and Mazlina, 2016). However, this negative aspect can be balanced against the enormous potential of information systems to contribute innovative solutions to both the mitigation of, and adaptation and resilience to climate change and other environmental problems. E.g. strategic use of information system in smart motor systems, logistics, buildings, and grids is valued to decrease approximately 7.8 billion tonnes (Gt) carbon dioxide equivalent ($CO_2e$), which can translate into approximately

€600 billion ($US 946.5 billion) of financial savings (Helen et al., 2012).

Present motivation of environmental concerns has changed from the indigenous scale to the worldwide scale, and has become the top concern of enterprise, governmental organisation, non-governmental firms and end users (Esfahani et al., 2015a). Therefore it is a known fact that the use of ICT consumes energy, and most energy production releases Green House Gases (GHG), which are a major cause of global warming and potentially damaging climate change. It is mandatory to design and deploy new approaches to limit the emissions caused by ICT use. IS can be of help since IS is a field which addresses the human and industrial issues associated with ICT, researchers, academicians and organisational practitioners in IS have taken up the Greening by IT cause and called it Green IS, which is the design and implementation of information systems that contribute to sustainability of business processes. According to Bokolo and Noraini (2016) Green IS are initiatives, strategies and programs that directly or indirectly address environmental sustainability in organizations. The researchers mentioned that Green IS refers to the development and implementation of information systems to support or enable eco-environmental sustainability procedures aimed to assist organisation in achieving their goals and objectives. Also in a different work by Bokolo and Noraini (2015), the researchers highlighted that Green IS offers promise for IS scholars to make significant contribution in reducing greenhouse gas emissions, achieve sustainability and reducing the effects of global climate change. Green IS has therefore become one of the latest considerations to improve organization's environmental sustainability whilst reducing the cost of IT processes (Bokolo and Mazlina, 2016).

Due to the significant increase in IT related power consumption and the resulting higher CO2 emissions, sustainability has gained considerable attention in software management in decades. Green IS in software management is an engineering paradigm encompasses the multi-faceted, global effort to reduce power consumption and the promotion of environmental sustainability in software processes (Jens et al., 2011). Thus, the concept of Green IS in software management is aimed at to reduce the environmental impact of IT and to facilitate the emergence of a more sustainable environment (e.g., by reducing CO2 emissions). In order to meet this goal, software industry increasingly considers Green IS as a way to address environmental issues of IT and envisions environmentally sustainable practices as the key to future success, as suggested by researcher such as Alemayehu and Vanessa (2009); Stefan et al. (2010). Presently software industries are searching for techniques to reduce IT-related energy consumption without huge investments in energy-efficient hardware. Thus software practitioners are in need of technology that are capable of reducing the environmental impact of IT hardware while at the same time provide software enterprise with large computing and storage capacity.

Murugesan (2008) mentioned that Green and sustainable practices include the design and manufacturing of environmentally sound and energy-efficient IT equipment, which can be achieved by adopting new techniques and materials that are both environmentally friendly and economically advantageous. It's also the implementation of new power management features as well as the production of recyclable materials. Also, Green practices include the reuse, refurbishing, and recycling of old IT equipment in environmentally sound ways (Murugesan 2008). Chin et al. (2015) added that green activity can be defined as an organization's environmental behaviour, including extensively environmental activities, which can assist practitioners in its decision-making process and can benefit the environment in cost and waste reduction. Chin et al. (2015) mentioned that Green processes implementation in software industries need large distinctive resources aimed at providing support to software practitioners. These resources involve intangible and tangible resources, such as technology, equipment, research/development, and human resources.

Thus this paper mainly focuses on the how software practitioners can make decision on how to integrate and utilize information system to minimize energy consumption of IT equipment, in the same time reduce CO2 emissions. The paper is organized as follows. Section 2 introduces the literature review applied for this paper. The research methodology is presented in Section 3; the proposed model is stated in Section 5. Section 6 finally states the conclusion and future work based on the contribution of the paper.

## 2. Literature Review

As mentioned above the challenges of sustainable Green practice in software management is due to several issues, one of which is the difficulty in making decisions on how to utilize and integrate sustainability in software management process. This section explores on decision making in software management, Green IS concepts, theories, existing models and frameworks.

### *2.1 Sustainable Practices in Software Industries*

The rapid growth in usage of computing and processing power in software development processes has resulted in a subsequent rise in software industries energy consumption and carbon emissions. This raises the issue of the sustainability of software industries. Currently in Asia, the electricity consumption of software industries servers and ICT cooling and power equipment results to significant proportion of the overall electricity consumption in the commercial sector. Therefore, it is essential to address software industries energy efficiency in order to guarantee that the associated impacts on infrastructure and environmental costs are mitigated. Sustainable practices in software industries must be synced to the buildings facilities and rooms which contain enterprise servers, cooling and power equipment for providing data



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services/communication networks for data processing, such as web hosting, internet, intranet, telecommunication and information technology.

Greening software industries has a significant investment in technologies and techniques for adopting best practices that are intended to improve both the energy performance and the environmental footprint. This can be achieved by software practitioners adopting best practice approach, where best practice is based on actions that match industry benchmarks and trends. It's therefore a practice that has been determined to produce superior results based on analysis of performance. However, in the context of Green software management process, this can be refined to encompass practices that improve energy efficiency while maintaining or improving software management processes. Thus best practices are typically integrated and implemented based on the directive from senior management and existing governance practices and processes (Stan et al., 2010).

According to Stan et al. (2010) to improve energy efficiency software practitioners have to reduce computer power usage through efficient application management, improve server efficiency, improve the efficiency of power supplies and distribution and improve the efficiency of cooling systems. Software practitioners can also integrate sustainable practice such as enable existing power saving features, rightsizing of UPS and IT equipment, efficient server consolidation and virtualization; optimize storage and proper re-configuration of enterprise server software.

### *2.2 Overview of Decision Making in Software Management*

A decision can be defined as the act of reaching a conclusion. Decisions can be structured, semi structured, or unstructured. The structured decisions clustering at the operational level of an organization and unstructured decisions at the strategic level. Decision making is becoming the basis of competitive advantage and value creations for software industries. Nowadays, software business environment is volatile, dynamic, demand for accurate, relevant, complete, timely and economical information. Poor decision making in software projects are due to unwillingness to commit to a decision, rely on others software team members for decisions, and not taking ownership of decisions, face conflicting priorities for decision and unstable practitioners availability of software team members (Noraini and Bokolo, 2015).

To have a successful software process it's needed to drive the decision-making process in order to emphasize software practitioners' abilities to practice green and sustainable practice in software management process. If decisions are right, it translates in positive software development outcomes, but where software activities are executed in conditions of poor decisions resulting from insufficient or inaccurate information, such software project could be in ruins. Thus sustainable decision making can assist software industries to increase the effectiveness and incorporating improvements aimed at better understanding, improved communication and more effective sustainable software management. In software management decision making is a critical software managerial function.

Good decision aids software process to be effective (Esfahani et al., 2015a; Noraini and Bokolo, 2015). Software management encompasses the knowledge, techniques, and tools necessary to manage the development of software products. Software management guides software managers to create plans for software development. Software management ensure that all of the project activities follow a certain predefined process, the activities are usually organized in distinct phases, and the process are usually organized in distinct phases, thus the process specifies what software module should be developed and delivered in each phase (Noraini and Bokolo, 2015).

### *2.3 Green Metrics in Software Management Process*

Green and sustainable practice by software practitioners incorporates many aspects such as ecological balance, politics, consumerism, technology, product purchases and consumption, marketing, manufacturing and resources. Greening in software industry refers to a process towards sustainability. Sustainability is the ability of one or more entities, either individually or collectively, to exist and thrive either unchanged or in evolved forms for lengthy timeframes, in such a manner that the existence and flourishing of entities are permitted at related levels and in related systems (Alemayehu, 2009).

Sustainability in software management is generally concerned with minimizing emissions, waste and water, improving efficiency and minimizing the total environmental footprint of a business. It often refers to meeting the needs of present generations without compromising the ability of future generations to meet their needs.

According to Hart (1997) it involves three general goals; pollution prevention at the end of a software product's use, product stewardship to minimize the environmental footprint during software produce use and clean technologies that reduce the use of polluting materials and develop environmentally friendly competencies.

The four most common metrics to rate sustainability in software management process are reduction in e-waste, reduction in energy consumption, reduction in Green House Gas Emissions and reduction in water (Mohamad et al., 2010; Alemayehu, 2009).

These metrics may not be necessarily mutually exclusive and are mostly correlated. However Alemayehu, (2009) mentioned that the reduction in waste, energy and water can reduce cost, improve software practitioners morale and create a Green industry brand equity and differentiation. Mohamad et al. (2010) introduced a new metrics to reduce the consumption of natural resources.

The new metric also aims to reduce the use of natural resources in software process by software practitioners.



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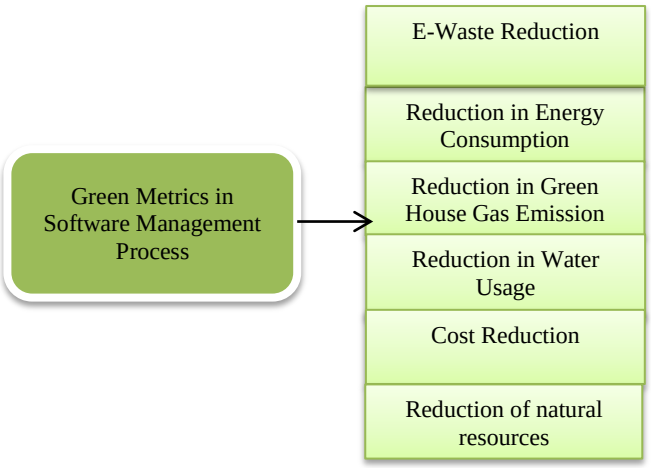


**Fig. 1.** Green metrics in software management process.

Figure 1, shows the Green metrics in software management process generally aims to reduce energy consumption, water use, pollution, waste generation, cost reduction and consumption of natural resources.
Greener practices encourage practitioners in organisation to substitute the use of toxic materials with non-toxic materials and non-sustainable practices/processes with more sustainable ones. Therefore, the Green IS can be seen as an inscription and enactment of sustainable intentions and actions in software management.

### *2.4 Green Sustainable Software Management Cycle*

Green Software lifecycle perspective mainly identify a set of processes involved in the development, adoption, use and disposal of IS in software processes. In software deployment, the process of design and development comprises the use of a set of tools and techniques for developing software, hardware and data structures to support emerging knowledge processes. In the use stage, the process involves practitioner's or industries' deployment of IS to execute software processes. This involves the acquisition, assimilation and diffusion of IS for software business benefits such as increasing effectiveness and efficiency, decision making quality and inter-industry collaboration. Once IS has been implemented and used, software practitioners, decision makers and stake-holders will formally and informally be involved in evaluating the usefulness, return on investment and benefits of the software system. The post-use evaluation is normally necessary to determine the continuity of software system use by software practitioners and end users.

Mohamad et al. (2010) mentioned that Green process lifecycle starts first with the design phase by considering the environmental aspects in the product/software design, material sourcing and production phases. Secondly, Green practice can be viewed as an outcome from the process and the use of Green product in developing and implementation process. Third, Green practice can also be regarded as the effect of the product/software after reaching its end of life, which can be expanded to cover the previous phases by taking the whole lifecycle into account (Mohamad et al., 2010). However, it's ascertained that sustainability can only be achieved through design of the software. This implies that in ensuring that the software management process is Green, attention should be given during the design and development processes. However, the approached implemented by software practitioners in accomplishing their tasks, in particular when designing and developing software for today's market (industries' and end users) needs to be reoriented towards designing environmentally sustainable software systems (Mohamad et al., 2010; Watson et al., 2010).

Therefore software industries can substitute the traditional, face-to-face business meetings that require travelling by video conferencing. Since video conferencing can facilitate eco-sustainability and promote communication. Hence when software practitioners utilize video conferencing; software industries can reduce not only their needs for business travels and its accumulative expenses but also traffic congestion as well as carbon footprints associated with travelling and mobility. According to Alemayehu and Vanessa (2009) Green IS in software process assist software practitioners by providing guideline in Green decision making when procuring/purchasing new IT infrastructure meant for supporting their Green and sustainable practices. For example Green IS can be used to track and manage software industries energy consumption.

The integration and utilization of Green IS will not only enable the industry to comply to the regulatory requirements but also in improving their economic performance in terms of cost reduction when energy is used efficiently in software process, thus reducing, the industries' carbon footprint which in turn gives the software firms a good name/branding due to its sustainable practices. Thus Bokolo and Mazlina (2016) mentioned that Green in software development process is the practice of designing, implementing, deploying, utilizing and disposing of computer, servers and supplementary subsystems efficiently and professionally with inconsequential or no effect on the environment, and with a strong focus on using IS to increase sustainability across the software industry.

Therefore Fig. 2 demonstrates the comparative levels of Green sustainable development among software practitioners. Fig. 2 also serves as a benchmark for measuring an industry's progress to participate in the global low-carbon economy by assisting software practitioners in reducing the environmental impact of emissions without necessarily changing the software management process. However a significant change in the software management process integration and utilization is intended to reduce the level of environmental impact based on the software management life cycle from design to end users consumption.
Fig. 2 illustrates how Green sustainable practice can assist software practitioners to integrate environmental thinking into software/product design, material sourcing/production,


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usage and end of life. Table 1 shows the Green sustainable process implemented by software practitioners.

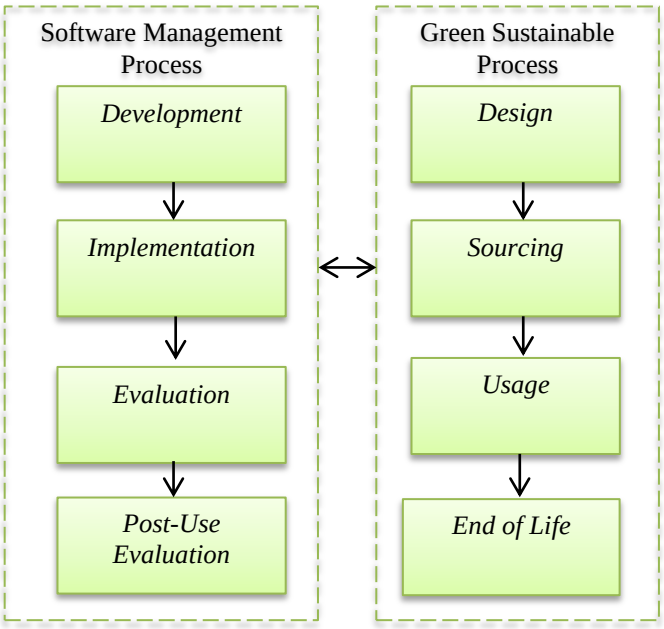


**Fig. 2.** Green sustainable software management cycle.

**Table 1**
Green Sustainable Practice Adopted from (Alemayehu and Vanessa, 2009).

| Green Sustainable Process | Description |
|---|---|
| Design | Green IS refers to the role of IS in supporting a business's overall sustainability initiatives Green IS. Green IS in software management therefore includes adoption of analytical IS for green software management, environmental management and carbon foot print analysis. It also includes IS based low carbon software solutions such as telecommuting, video-conferencing, thin client and web based business services, virtual collaboration and IP telephony. |
| Sourcing | Green IS implies the practice of environmentally preferable IT purchasing. This involves carrying out of sourcing practices such as analysis of the environmental foot print of an IT hardware in software process, evaluation of the green track record of software and IT services providers, incorporating green issues such as recyclable design and packaging in merchant evaluation, and inclusion of social concerns such as the presence of harmful materials in IT software process in IT procurement decisions. |
| Usage | Green IS implies improving energy efficiency in powering and cooling corporate IS assets and reducing IS induced greenhouse gas emissions. Two types of energy consumption reduction can be identified, temporary and structural consumption avoidance. While temporary avoidance refers to optimization of energy utilization without reducing the installed power base, structural avoidance results in reduction in installed power capacity. A number of green technologies, IS and practices related to the two categories can be used as indications of the integration and utilization of Green IS operation |
| End of Life | Green IS refers to practices in reusing, recycling and disposing IT hardware. |

Table 2 show the software management process adopted by software practitioners.

**Table 2**
Green Management Process.

| Green Management Process | Description |
|---|---|
| Development | This phase determines who is going to use the software system. This phase also determines how users will use the software system either via a web-based system or application based platform. Thus this phase determines the system architecture to be used in deploying the software system. This phase also determine the system interface design. Hence the software system interface is supposed to be simple and easy to use. |
| Implementation | This phase involves the coding of the software system using a programming language such as Java, C++, .NET, HTML5, CSS, PHP, MySQL, JavaScript, Python Programming etc. |
| Evaluation | This phase involves running the developed software system in a deployment environment to test the system against the requirements and detect any errors and bugs in the software system. |
| Post-Use Evaluation | This phase involves the future functions that can be integrated into the software system to see what improvement can be made. It involves the evolution of the software system in response to changing end users' needs in form of software updates and patches. |

### *2.5 Related Works*

The concept of Green IS and sustainability can be applied to software management process in two different ways either as Green in software systems (Green IS) or as Green through software systems; (Greening by IS). However, it's not clear how sustainable decision making can be systematically carried out as an objective in software management process. Presently, there are few models, descriptions or realizations in the area of software management, computer software and software process models. Stefan et al. (2011) developed a reference model for green and sustainable software and its engineering (GREENSOFT Model). The model addresses both challenges in the reduction of the energy and resource consumption in ICT, as well as the use of ICT to contribute to software development. The model is conceptual reference for Green and Sustainable Software development aimed to support software practitioners in creating, maintaining, and using software in a more sustainable way. The model comprises a holistic life cycle model for software products, sustainability criteria and metrics for software products, procedure models for different stakeholders, and recommendations for action, as well as tools that support stakeholders in developing, purchasing, supplying, and using software in a green and sustainable manner. The model has the objective to assess the ecological, social, human, and economic compatibility of a product during its whole life cycle. The model begins with the early stages of product development and ends with the product's disposal and recycling. The findings gained from these assessments can then be used for a balanced


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optimization of the product or for comparing a product with its competitors.

Markus et al. (2013) presented a model that integrates Green IT aspects into software engineering processes with agile methods in order to produce greener software from scratch. The model aims to address the energy consumption of ICT that is currently increasing. The model utilized agile extension for software development processes that aims at an early integration of sustainability issues into arbitrary software development processes. It sets an organizational frame that allows the software development team to take over the responsibility for design decisions that have a direct impact on the environmental and, regarding hardware requirements, also on the social impacts of the software product. The researchers also suggested that in a sustainable Green software process there is need for a lesson learned, best practices regarding sustainability issues of software products and development processes, decisions for future projects, group reflections on effects, and impacts of software management processes. These information should be preserved for future projects, e.g. in a knowledge base, a process handbook, etc.

Birgit (2015) contributed by suggesting a checklist and guide word based approach that shows how to include the objective of environmental sustainability from the very early steps in finding the stakeholders and analysing the domain to the definition of a usage model and specific requirements. The researcher believes that sustainable software is energy efficient, minimizes the environmental impact of the processes it supports, and has a positive impact on social and/or economic sustainability. These impacts can occur directly (consumed resources), indirectly (mitigated by service), or as systemic effect. Mohankumar and Anand (2015) propose a new software model called as System Development Life Cycle (SDLC) Energy Star Model in each phases of the life cycle of Software Engineering. The model aims to provide a clear idea about how to achieve the Green and Sustainability in SDLC phases (Software Development Life Cycle).Thus the researchers proposed to implement the star values and tried to achieve the Green and Sustainability in SDLC.

Patricia et al. (2013) explored initial challenges for Green software engineering, by highlighting how software can contribute to decrease power consumption, become greener in at least two ways. First, by being more energy efficient, hence using fewer resources and causing fewer CO2 emissions. Second, by making its supported processes more sustainable, which is implemented by decreasing the emissions of governments, companies and individuals, thus enterprise software must be completely rethought to address sustainability issues and support sustainable and to develop an innovative business models and processes. Juha (2011) researched on Green software quality factors. By stating that in achieving a sustainable software development and a stop climate changes, good software can help to reduce greenhouse gases, waste and resources requirements while bad software increases these wastes. The researcher mentioned that to understand how good, bad or beautiful software process is, there is need to understand relevant software quality such as *feasibility*, which is how resource efficient it is to develop, maintain and discontinue the software system. *Efficiency*, how resource efficient it is to execute software and last sustainability, how software supports sustainable development. Thus a sustainable green software management process is supposed to provide support for green education, in using the software system to support education and general knowledge about sustainable usage. Also a software management process is supposed to aid in decision support, by providing software process and tools for environmental friendly software design, implementation, operation (usage) and end of life (disposal& recycling). Lastly software management process supposed to lower IT energy and support better climate and environmental models.

Nuttapon and Gabriel (2012) carried out research on the analysis of Green and sustainable Green principles and practice in Dell and Toshiba and suggested that environmental impacts are caused by the Information Technology infrastructure in various areas such as greenhouse gas emissions, polluted water, hazardous waste, etc. Therefore, the Green principles were implemented into each section of the ICT infrastructure, to reduce those environmental impact problems. However based on the data inspired by Dell Inc. and Toshiba Corporation Corporate Social Responsibility reports, the researchers stated that companies are trying to minimize or eliminate the environmental impact of IT and to support the managing sustainable environment.

Therefore, Green IS is about improving or maintaining computing performance, while reducing the energy consumption and the carbon footprint. However, implementing Green IS principles into practice involves the usage of many resources. Software industries have to spent large sums of money in order to reconstruct their IT infrastructure, thus its suggested that Green IS should be implemented into the IT industries as set of best practices for optimizing the usage of computing resources since Green and sustainable practice were created not only to protect the environment and to save energy, but also to reduce firm's expenses on the long-term.

## 3. Research Methodology

This research paper followed a literature review approach as the main method. A literature review method is suitable for creating a theoretical foundation for advancing knowledge and conceptual development. Review of secondary data involves three sequential activities of input, process and output. Thus, first relevant articles were identified from various online libraries. The articles were screened by reading mainly the abstracts and the whole papers. The review of the literature aimed to research and creates a clearer conceptualization of Green IS in software management process. Thus the review of Green IS, sustainability relating to software management/Green software engineering academic and practitioner literature as well as literature on the technical, social and process views of software practitioners has been undertaken. In the course



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of the review, key concepts revolving around Green sustainable software management process are noted down which helped to identify the variables and develop the proposed model that will assist decision making for sustainable software management process.

### *3.1 Approaches for Green Sustainable Software Process*

Alemayehu and Vanessa (2009) contributed to Green and sustainability by stating that Green and sustainable in industries research can be considered as a holistic and systematic approach that's aimed to address the challenges surrounding environmental sustainability. They mentioned four main contribution of IT in Eco-sustainability goal. These goals can be related to the scope of this paper which is mainly concerned on how to attain a sustainable decision making in software management;

i. Information systems infrastructure- such as data centre energy efficiency.
ii. Information systems contribution- to reducing the environmental impacts of business IT activities such as through adopting green technologies.
iii. Information systems support- for environmentally sustainable business practices such as in enabling green supply chain management through carbon foot print monitoring and building tools for energy management options.
iv. Information systems role- such as supplanting high CO2 emitting business practices in the low-carbon economy.

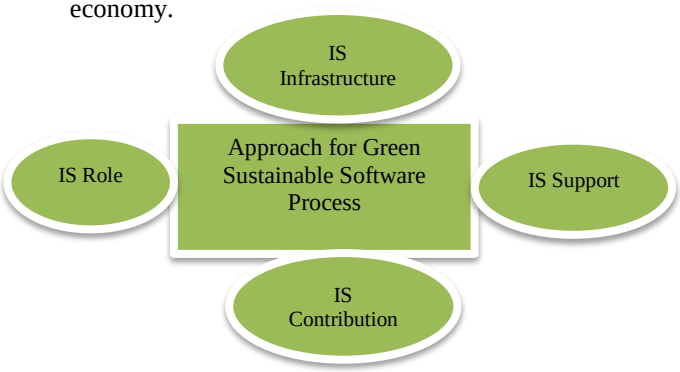


**Fig. 3.** Green sustainable process approaches.

### *3.2 Decision Making for Green Sustainable Software Management*

Green sustainability in software management process is usually associated with technologies and techniques for improving the energy efficiency of software process, for reducing the environmental impact of IT usage & software operations, and the use of IS as an enabler of industry wide Green initiatives. Green sustainability in software management involves not only hard technological solutions but also soft business practices and managerial actions to make sustainable decision making as eco-friendly as possible in software management process in software industries (Alemayehu and Vanessa, 2009).

Helen et al. (2012) suggested that there is need for a decision support for environmentally sustainable development. The researchers added that existing IS literature contains large numbers of articles on how business, government and community organizations all rely on information systems to support their decision making. Presently software industries are facing issues in making decision related to the welfare of the environment. Thus, a decision making model for Green sustainable software management integration and utilization is therefore needed to provides useful insights as to what extent eco-sustainability considerations are influencing the decision making process in managing software (Alemayehu and Ahmad, 2012).

The model can help to determine software industries concern for the natural environment, even if economic benefits are not tangible in the immediate short term, it can influence the utilization of IT in software process. Thus understanding the model variables is useful to software practitioners and software managers as it helps them to justify their Green and sustainable actions and to effectively participate in the firms sustainability practices. The production, use, and disposal of IT have a direct effect on the natural environment and eco-sustainability. Each stage of IT lifecycle from manufacturing to usage and disposal poses environmental problems.

In addition, IT might have had an undesirable impact of increasing the expansion of environmentally polluting. The average lifespan of IT, e-waste is emerging as one of the fastest growing waste that requires serious attention. Furthermore, energy consumption by software industries facilities such as data centres indirectly contributes to CO2 emissions. Therefore, both IT hardware manufacturers and software industries using IT need to apply principles of environmental sustainability, which include pollution prevention, product stewardship and clean technology or sustainable development in managing IT (Hart, 1997; Alemayehu and Ahmad, 2012). Helen et al. (2012) also mentioned that modern decision support tools are needed to assist practitioner in diffusing Green practices. The challenge for environmental, sustainable climate change problems is to create decision support approaches that can be applied in software management and across several domains.

### *3.3 Green Software Quality Properties*

Green software quality properties are non-functional requirement to be considered in Green software processes. Accordingly Stefan et al. (2011) added that the quality properties modifiability and reusability take effect in the software development phase, whereas the properties portability, supportability, performance, dependability, usability, and accessibility take effect in the software usage phase. The software process related predictability property; software practitioners ability to accurately estimate effort and cost upfront and efficiency which is overhead of software production processes over the bottom line value perceived by the end user also take effect in the software


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development phase, as well as the project's footprint; natural resources and environmental impact used during software management process.

However, portability is mainly concerned with the background of hardware obsolescence, which means that the lifetime of hardware should be prolonged to the end of its useful lifetime, instead of causing its early replacement due to hardware requirements enforced by a software product. In their research Mohankumar and Anand (2015) mentions the software metrics that depends on the quality properties modifiability and reusability take effect in the development phase, whereas the properties portability, supportability, performance, dependability, usability, and accessibility take effect in the usage phase.

Thus desktop PCs should not be used for less than roughly 5 years. After 5 years of routine deployment, the eco-environmental impacts resulting mainly from the energy utilization of the *usage phase* overshadow those of the *production phase*. Unlike, Software system servers which are diverse because a server in 24/7 operation mode extents to the point of equilibrium earlier after approximately 1 year of use.

Due to the fact that there will be greater rates of renewable energy and more energy effective hardware in the future, the *usage phase* outperform these of the *production phase*. Thus, software induced hardware obsolescence is of particular importance. Hence, hardware obsolescence should be a genuine quality property of green and sustainable software. Software industries that develop Green and sustainable system software should be committed to environmental and social responsibility by covering environmental and social standards throughout the entire software management process, which are necessary to develop, advertise, supply, and dispose/recycle the software system (Birgit, 2015). Patricia et al. (2013) mentioned efficiency, compatibility, usability, reliability, security, maintainability, controllability, repeatability and portability as Green properties in software management processes.

### *3.4 Sustainable Green Decision Making Metrics*

A *metric* is a standard of measure of a degree to which a software systems components or process possesses some property. Thus metrics can be said to be units of measurement or a set of specific measurement taken on a particular software component, item or variable. *Measurement* is the real assessment of a dimension that can be performed by a metric or the calculation of a value based on one or more measurements. Reducing energy consumption and carbon footprint, in order to achieve high levels of sustainability, are some of the challenges that the IT community is pursuing to deal with environmental issues generated by IT systems. In order to make a sustainable decision making in software management process, Table 3 shows the metrics to be considered by software practitioners in making sustainable decisions on how they manage their software processes.

**Table 3**
Sustainable Green Decision Making Metrics Adopted from (Paolo et al., 2013).

| Green Software Metrics | Measurement Unit | Description |
|---|---|---|
| Energy | Joule (J), Index, Watt (W),Ampere (A) Kilowatt-hour(kWh), Number, byte/kWh | This metrics is designed to measure energy and power consumption or saving from software processes. Energy metric can be used to perform assessments on software system components. It's also used to estimate software system energy consumption in the industry. Energy metrics measures energy consumption per computing application unit. |
| Performance | GFLOPS/kWh , Computing Unit/kWh, Percentage (%), Seconds (s), Index, Number | Mainly measures performance indices, such as throughput, response time. Throughput metric is classified as Performance type because it measures a performance index, which is the number of service requests served at a given period of time. |
| Utilization | Percentage (%), Megabyte (MB), Megahertz (MHz), GB/s | Focus more on the measurement of computing resources, such as storage, memory, hard disk and I/O operations. This metric can be used to measure CPU Usage metric, which is the utilization type metric because concerned with the relative CPU utilization of specific applications. |
| Financial Cost | US Dollars ($), Malaysian Ringgit (RM) | This metrics aims to evaluate or to estimate the costs of green policies application, the costs of software management process in industry at any stage. Additionally, Financial Cost metrics measure the money earned from energy savings. Where the financial cost metrics measures the total software management process lifecycle expenses, including costs of conceptual blueprint/modelling, design, development, requirement analysis, deployment, evolution and maintenance. In summary Financial Cost metrics is used as a common currency to express economic values. |
| Performance & Energy | GFLOPS/Watt , Index | Is a combined metrics that measure both performance dimension and energy consumption or saving. It is classified as Performance/Energy because it estimates how efficiently the power is used within a software system. It is a measurement of energy consumption input with response to the service output. |
| Pollution | CO2 units | This is the measurement of pollution generated by software process and software utilization/integration usage by software practitioners. Pollution metric describes the index of carbon emissions, being caused by transportation, logistics, in software process required for the software development. Thus Pollution metrics indicate the amount of pollution generated by the execution of hardware services and software applications. |



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## 4. Proposed Model

Green and sustainable software system can only be achieved, if the software practitioners in the industry are aware of negative and positive impacts on software management process that will likely be caused when using the software system. In order for software practitioners to reducing these impacts, it is necessary to institutionalize Green practices in their software process. This makes sustainability disputes controllable and places software practitioners in a position to efficiently optimize their software product. Additionally, it is necessary that the development process itself is environment friendly. Green and sustainable software management process is the art of developing eco-environmental software with ecological and sustainable software paradigm.

Therefore, it is the art of designing and programming software products in a way, so that the negative and positive impacts on sustainable development expected from the software product over its whole life cycle are continuously evaluated, reported, and used for a further enhancement. Hence this paper develops the model to aid software practitioners in sustainable decision making for Green software management process. Presently there are research that states the important of sustainable decision making in software management process (Stefan et al., 2011; Mohankumar and Anand, 2015; Mohamad et al., 2011; Alemayehu, 2009; Chin et al., 2015; Esfahani et al., 2015c; Jordi et al., 2009). However, there are few available model/framework aimed to assist software practitioners in integrating and utilizing Green IS for sustainable decision making in software management domain, thus the model is proposed as seen in Fig.4.

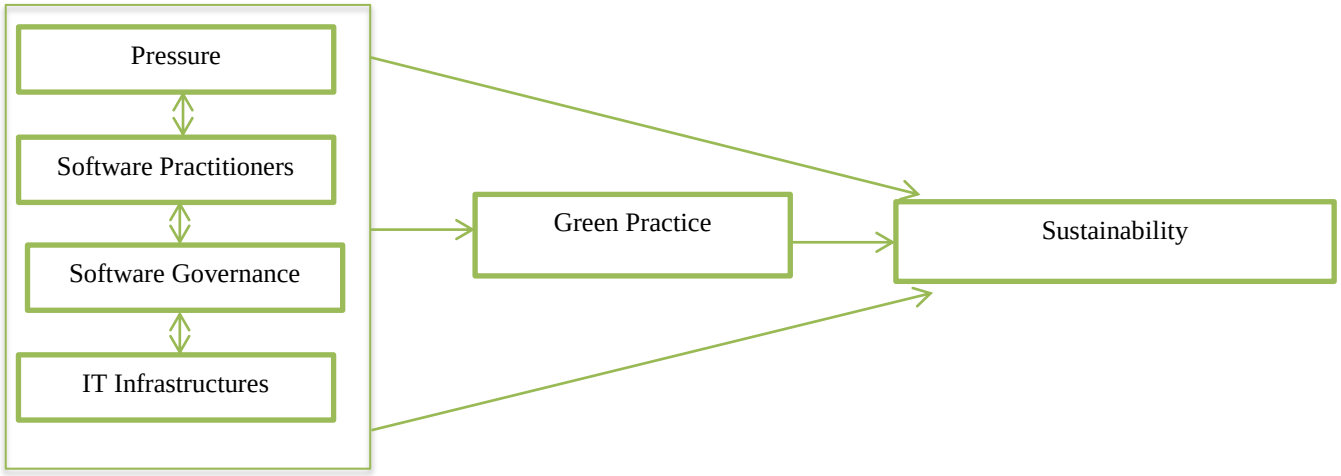


**Fig. 4.** A decision making model for sustainable software management.

Fig. 4 shows the model that will assist decision making for sustainable software management process. The independent variable (IV) is the input or the case of something, dependent variable (DV) is the output or the effect of something and mediating variable (MV) (Siti and Ruziah, 2012), thus DV depends on IV, while IV influences DV. As seen the Fig. 4 the arrow points from IV to DV.
MV a mediating variable is one that functions as a mediator or intermediary between IV and DV. The model comprises of the independent variables (IV), the mediating variable (MV) and the dependent variable (DV), the dependent variable dependents on the independent variables and the mediating variable. The model consists of four independent variables (Pressure, Software Practitioners, Software Governance and IT Infrastructures), one mediating variable (Green Practice) and one dependent variable (Sustainability). Single arrow implies "causal relationship", which can be analysed using hierarchical regression, path analysis or Structural Equation Modelling (SEM). Double arrow implies "mutual relationship", which can be analysed using case study. This model can also be used as a research model or a conceptual model in the domain of sustainability in software management discipline. The model provides software practitioners with new insights and enables a more systematic application of sustainable practices in software processes.

### *4.1 Independent Variable (IV)*

a. Pressure

Pressure is a variable that influences sustainability decision making goal in software industries. These pressure are *economic pressure* mainly stems from rising energy costs, leading to the need for enterprises to reduce power consumption of IT hardware. Lowering energy costs is often associated with the aim to achieve competitive advantage. Another is *governmental pressure* for Green IT mainly stems from various forms of environmental standards and regulations imposed by governments around the world. *Social pressure* is exerted by the increasing end users/clients demand for Green solutions and the increased


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positive public perception of Green initiatives (Jens et al., 2011). Pressure can also influence software practitioners' integration of Green practices, such pressures includes mimetic, coercive, and normative pressure.

*Mimetic pressure* reflects the pressure to imitate structurally equivalent successful industries in the same industry without necessarily considering the industry-specific context. This occurs when other software competitors having already successfully adopted Green software management process results in a reduction of power consumption. This will induce other software industries to adopt such Green practices in their own software processes. Adela et al. (2011) believe that mimetic pressure happens when software practitioners copies other industries' environmental behaviours in pursuit of legitimate practices. *Coercive pressure* is pressure that comes from the societal expectations and dependencies towards software industries. Moreover, government and industry regulations enforce coercive pressure on software industries and assertively force software industries to adopt Green practices. According to Adela et al. (2011) coercive pressures are often associated with powerful actors upon whom an industry depends on.

*Normative pressure* arises from the exchange of best Green practices among software partners, software vendors, and the government. The information exchange within the software industries provides software practitioners with guidelines how to assimilate sustainable Green practices efficiently and provides them with access to first-hand experience with Green ecological and economic software benefits (Jens et al., 2011; Adela et al., 2011).
Adela et al. (2011) also stated that normative pressures occurs when software industries feel compelled to honour certain practice oriented expectations from professional circles or the society at large.

b. Software Practitioners

These are software managers, professionals, software system designers and software developers. The software practitioners' commitment is mandatory in software management process because they are involved in planning, implementing, validating, deploying and maintaining the system software with eco-sustainability considerations in mind (Bokolo and Noraini, 2015). Thus software practitioners collaboration is based on their shared interest and stakes in fulfilling the objectives or requirements of the industry, which is to develop a quality software in due time and at a lower cost (Bokolo and Noraini, 2016).

c. Software Governance

Software Governance refers to the software firms' management to implement Green practices. Software Governance offers a medium for defining the software process. It is the operating pillar that defines the administration of Green initiatives in software industries. Software Governance is a variable that defines the software administration decision making (roles, responsibilities, accountability and control) of Green software initiatives. Software Governance also includes allocation of finance and other resources to Green software initiatives and defining metrics for evaluating the impacts of Green software initiatives (Stan et al., 2010). Thus management policies and regulations towards Green and sustainable practices implementation in software processes can improve efficiency, and care for the natural environment. However, the goal of software governance is generally to enhance greater resource utilisation and cost reduction of doing business. Such aims are in line with the notion that firm is bound to assure shareholders or software practitioner that the firm makes adequate profit. Therefore, any decision concerning sustainable Green practices is likely to be based on a cost benefit analysis (Stan et al., 2010).

*d.* IT Infrastructures

The IT infrastructure used in software management process is identified as an important variable in attaining a sustainable decision making. The infrastructures are the hardware, software and network facilities. Green sustainable software process is likely to succeed in industries that have smaller installed IT assets. Software process that run high density servers are likely to feel the pressure of rising electricity costs and the challenge of powering, cooling and housing those technologies. This might lead to the utilization of more energy efficient servers, server consolidation and virtualisation technologies (Alemayehu, 2008). Green software management also involves acquiring more environmentally effective Greener technologies. Thus IT infrastructures are key driver of Green practice. Some of the commonly integrated Green infrastructures include server virtualisation, data centre energy optimisation and rightsizing IT equipment (Alemayehu and Vanessa 2009; Mueen et al., 2012).

*4.2 Mediating Variable (MV)*

a. Green Practices

This is the mediating variable that mediated between the IV and the DV. The practice variable is the current software management process carried out by software practitioners in software industries (Esfahani et al., 2015d). Based on the work from Stefan et al. (2011) five main variables in software management are considered in integrating and developing Green sustainable software. They include development, distribution, operation, disposal and deactivation. However based on other works by Bokolo and Noraini (2016); Alemayehu and Vanessa (2009); Alemayehu (2008); Bokolo and Noraini, (2015); Alemayehu et al. (2008); Alemayehu (2009); Alieen and Wui-Gee (2011) a new phase is added which is the sourcing phase.



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- Sourcing

The sourcing captures the extent to which environmental considerations are considered in software process and other software related purchasing decisions, where the purchasing of software related components are increasingly driven by ethical concerns. Green issues may not only have an impact on software practitioners buying power, but also affect how software is been developed. However, Green sourcing revolves around evaluating the environmental behaviour of software vendor and partnering with software practitioners to improve developed software. Green sourcing practices also include promoting the use of Green technologies during request for proposal processes and shortening IT equipment refresh periods to gain access to energy efficient equipment. The involvement of software vendor is a critical element of Green software sourcing practice (Alemayehu and Vanessa, 2009).

- Development

This account for impacts on software management process that directly result from activities involved in software process, as well as indirectly involved software activities. In the development practice environmental impacts includes, electrical energy that is necessary to power the workstations of software practitioners and other software team members, electrical energy and natural resources that are necessary to operate the ICT systems such networking devices, servers, and storages, energy for moving purposes like long distance commercial trips for software team meetings with stack holders /end user and the development team. Some of these impacts can be controlled by utilizing teleworking and teleconferencing, or by substituting material products with suitable immaterial substitutes. The development phase also accounts for impacts from software system/application maintenance and updates in the sense of bug solving, since this is also a software process (Stefan et al., 2011).

- Distribution

This accounts for impacts on software management process that results from distributing the developed software system or application. This comprises environmental impacts, such as the shipping of finished goods e.g. foam, polyurethane, plastic, biodegradable material, or data hardware storage medium such as CD/DVD, USB memory stick (Bokolo and Noraini, 2015; Stefan et al., 2011). Furthermore, going Green may involve the distribution of software products as download, which is presently common. Also the download size should be considered, as well as the electrical energy and material assets that are necessary to operate the required IT facilities (Stefan et al., 2011).

- Operation

The operation mainly considers impacts that result from using, running, deploying and maintaining the software system/application. Where, maintaining means that software/system administrators are in charge of installed software and support users in their firm. Thus, operation includes activities such as the installation of software updates and patches, the re-configuration of computer software and systems, and the training and educating of other practitioners in regards to proper software application/system usage. The operation phase also involves the re-configuring of software application system in a way that it consumes less power, or the setting of computer control to suspend mode when it is idle for 10 minutes (Stefan et al., 2011).

- Disposal and deactivation

The disposal and deactivation accounts for impacts on software application and systems that result from disposal and recycling of software material and sub software products. If a software application product is taken out of service, it is mostly essential to convert the existing data to a format that can be managed by the succeeding software application system, or to make it available in some other ways (Stefan et al., 2011).

### *4.3 Dependent Variable (DV)*

According to Alemayehu and Vanessa (2009) sustainability has strategic implications for software management process in regard to software production economies, cost competitiveness, investment decisions making and software asset assessment. Hart (1997) proposed that sustainability in organisation can measured based on three stages of eco-sustainability namely, pollution prevention, product stewardship and clean technology.

#### *a. Pollution Prevention*

Focuses on the control and prevention of polluting emissions and effluents during organizational production and operations processes. Pollution control means cleaning up waste once it has been created, thus can be achieved via the use of pollution control equipment, whereas pollution prevention means minimizing or preventing pollution before it occurs and can be achieved via improved management, material substitution, recycling or process innovation (Hart, 1997; Bokolo and Noraini, 2015). Therefore pollution prevention aims to generate significant savings, especially during early stages, resulting in cost and productivity advantages over other organizations (Hart, 1997). In summary pollution prevention aims to minimize cost of installing and operating emission control equipment's, reducing cycle times, reducing the industry's compliance and obligation costs.



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*b. Product Steward*

Product stewardship requires environmental impacts to be considered throughout the entire software development lifecycle of the industry, including raw material procurement, software design and deploying processes (Bokolo and Noraini, 2015; Alemayehu and Vanessa 2009). Product stewardship aims to decrease the overall software development life cycle environmental expenses of a software product by correcting the development and implementation process with the objective of the industry. Its objective also involves mitigating the environmental footprint of actions at each step of the software management process and achieving system transformation from design to evaluation.

*c. Clean Technology*

Clean technology, requires savings in technologies of the future. Such technologies can cause substantial changes in the software management process with a view to reducing the level of environmental effect along a software product's life cycle from development to utilization (Hart 1997). Clean technology aims to reduce the environmental impact of industries economic activities across the world (Alemayehu and Vanessa 2009). On creating long term solutions rather than short term gains by visualizing and implementing clean technologies (e.g., substituting synthetic chemicals with organic substitutes) (Hart, 1997; Adela et al., 2011; Bokolo and Noraini, 2015). According to Bokolo and Noraini (2015) clean technologies involves the use of modern application or systems in software processes by integrating practices that enhance and preserve resources, non-polluting low waste and energy efficient processes. Compliance software can be used by practitioners in product/service development for supporting organizational decision making and creation of knowledge for eco sustainability. This can be seen as a Green sustainable software practice. Table 3 shows sustainable practice in software industries based on work by Watson (2008); Hart (1995); Bokolo and Noraini (2015).

**Table 3**

Sustainable Practice in Software Industries (Watson, 2008; Hart, 1995; Bokolo and Noraini, 2015).

| Sustainability in Software Industry | Software Practitioners | IT infrastructure | Pressure and Software Governance |
|---|---|---|---|
| Pollution Prevention | Software practitioners should turn off their computer when not in use for some hours. They should also print on both sides of a sheet of paper, turn on the energy conservation preferences for their operating system, this will enable the computer to sleep mode after a certain period of inactivity. | Reduction of emissions and e-waste by switching to thin clients. A thin client contains significantly fewer components and has a longer life expectancy than a regular PC. Implementing server virtualization which has become a popular energy saver. Virtualization means doing more work with fewer resources, which in turn free up data centre space and lowers energy bills. | Migration from the postal system to electronic networks. |
| Product Steward | Recycling used electronic products. By taking unused, old, outdated unwanted computers and refurbishes them and when they decide to dispose of an electronic product, check its manufacturer's web site for recycling options and procedures. | Reuse components, recycle computers from past software projects.<br>Software industries can also use cleaner technology such as solar or hydro power to power their data centres. | Governmental policies, societal norms. Policies that encourages recycling. E.g. in Malaysia Starting 2016, the Government instructs the society and companies to separate recycle material form non-recycle material when they dispose their domestic wastes and refuse. |
| Clean Technology | Paperless interaction and paying software related bills online is a relatively easy change with a positive impact on the environment. Since it's faster and more convenient will reduce paper usage in bill printing. Electronic media can be more environmentally friendly than paper. | Face-to-face meetings can consume considerable energy when the attendees are scattered across the globe. Video conferencing is a good alternative, particularly with today's high quality systems. Video conferencing can transcend distance to replicate face-to-face communication. These collaboration tools can help to bridge the distance when a meeting's participants or a work team are in different locations. | Downloading software related medias via the internet rather than procuring from a local store.<br>Emailing software process rather than posting a letter is cleaner than a software process in which information exchange is based on paper and the postal system |



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## 5. Discussion

Sustainable development was defined by the United Nation as meeting the needs of the present without compromising the ability of future generations to meet their own needs. However sustainability depends on the population at large, but people sustain what they value, which can only be derived from what they know (Birgit, 2015). In sustainable Green software management processes the development, maintenance, and disposal must save resources and reduce waste. Software practitioners should ensure that when developed software is deployed and runned, resources should be saved and waste should be reduced (Markus et al., 2013). However, in every decision regarding Green sustainable software process, software practitioners must bear in mind that every additional software component consumes additional energy in running and execution (Stefan et al., 2011).

Green and Sustainability in software management seeks software solutions to sustainability issues in software process and aims to limit gaps between the natural and social sciences through the practical application of Green practices for decision-making (Michael and Aparna, 2010; Esfahani et al. 2015a). Green or sustainability signifies all activities and efforts integrating ecologically friendly processes and technologies into the software process lifecycle. Green IS aims to utilize IT infrastructure to change industrial processes and/or practices to enhance energy efficiency and reduce the environmental impacts, and to introduce environmentally sound software products and/or services (Esfahani, et al., 2015c). Presently, software industries are under overwhelming pressure from end users, private institutions and government to improve their environmental sustainability.

Based on the research by Esfahani et al. (2015b) sustainability in industries are initiatives aimed at mitigating industry's impact on the natural environment, in which these initiatives can include changes to the firm's products, processes, and policies such as reducing energy consumption and waste generation, using ecological sustainable resources, and implementing an environmental management system. However, integrated approaches which co-ordinates people, processes, technology and data are needed to achieve environmental objectives

Although, Green IS is still in its infancy. Contributions to the domain of Green IS have evolved since the last decade. The research area of Green IS continues to gain traction as both academicians and practitioners look for innovative ways of using systems to help achieve environmental sustainability objectives. Green IS is embedded during the design and implementation phases of software management process and has impacts which are visible to software practitioners. Green IS can play an enabling role in environmental protection through the reduction of Greenhouse Gases (CO2) and other sustainability issues. Green IS certainly has the potential to greatly assist in shaping the industrial scene of the future (Keith et al., 2013; Chris et al., 2014).

Green practice can contribute to sustainable Green software processes by reducing software transport costs through fleet, delivery, or vehicle routing management systems that minimize traffic congestion and energy consumption (Bokolo and Mazlina, 2016). Green IS enabling virtual collaboration between remote software teams, thereby reducing the impact of travel. Green IS also supports geographical working through systems that enable virtual collaboration. Green IS can also support software management by monitoring and analyse environmental information such as toxicity, energy used, water used, carbon emissions etc. Provide information to software practitioner and team members to facilitate decision-making under consideration of green choices (Stefan et al., 2010; Bokolo and Noraini, 2015).

## 6. Conclusion and Future works

Presently software industries are taking steps toward understanding what it means to be Green. Information systems (IS) are now known as a critical lever for decreasing firms' carbon footprints, with a great potential to outweigh their negative impacts on the environment. Green IS in software management process mainly involves energy efficient hardware and software, to complex environmental management systems. Despite increased attention to Green practices by software practitioner, research highlights that the initiation of such initiatives is still in its foundation and involves new issues for software industries. One of such issue is for how software practitioners can implement a sustainable Green decision in software management. Thus it's quite difficult for software practitioners to make decisions on how to integrate Green practices into their current software process.

Therefore this paper provides a preliminary insight into the utilization and integration of sustainability in software management process as well as the variables (IV, DV and MV) that influence eco-environmental practices by proposing a model that will assist decision making for sustainable software management process. In this research paper, the contributions of Green information systems to the objectives of software management process are examined by exploring secondary data from literature. The propose model can be utilized by software practitioners, academicians, researcher and software industry to infer on how to integrate Green and sustainable practices into their software management process.

The model provides the independent variable (Pressure, Software Practitioners, Software Governance and IT Infrastructure), mediating variables (Green Practice) that influence the dependent variable (sustainability) in software industries. The model also discusses on the current Green software management phases (mediating variables) which are based on previous work. The model can also be used as a conceptual or research model for researchers to investigate on. Future work will involves the refinement of the model variables and the evaluation of the proposed model using a mixed research mode (quantitative and qualitative research). The relationship among the IV,



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DV and MV will be checked using Structural Equation Modelling (SEM), whereas the IV and MV variables will be verified using case study in Malaysian Based Software Organisation.

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**Author Biographies**

Bokolo Anthony Jnr. is currently a PhD candidate in Computer Science at the Faculty of Computer Systems and Software Engineering, Universiti Malaysia Pahang (UMP). He completed his MSc in Computer Science, Research Mode from Universiti Putra Malaysia (UPM) in 2015 and his BSc in Software Engineering (Hons) from the University of East London (UEL) in 2012. He currently works on Research and Development and has published more than a dozen papers. He's research interest includes Green IT/IS, Software Management, Risk Assessment & Mitigation, IT Governance, Collaborative Enterprise, Software Agents and Knowledge Codification.

Mazlina Abdul Majid is currently an Associate Professor of Computer Science at the Faculty of Computer Systems and Software Engineering, Universiti Malaysia Pahang and currently the deputy dean (research and post graduate studies) in Faculty of Computer Systems and Software Engineering, Universiti Malaysia Pahang. She has a Doctoral Degree (PhD) Computer Science from University of Nottingham, UK in 2011. M.Comp.Sc (Software Engineering) with Honour from Universiti Malaya, 2004 and B.Sc. Computer Science, Universiti Teknologi Malaysia in 2000. Her current research areas includes Discrete event and Agent Based Simulation, Human Behaviour Modelling and Human Computer Interaction.



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