A New Green Software Process Model for Sustainable Software Product

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Abstract

Green and sustainability issues are being considered as the alternative effort to ensure the long-time usage and durability of software that targets minimal negative environmental impact. Sustainability usually relates to economic, environmental and social views. To achieve and maintain sustainability in software, waste management is one of the essential considerations because it affects the environment in general. Even though waste is often associated with manufacturing, it can also occur in software processes. Researchers believe that waste reduction will improve the efficiency and productivity of work. Previous studies emphasise green hardware with respect to energy consumption, power consumption, waste reduction and disposal. However, there is a lack of studies on green software, even though the software indirectly impacts the environment. Several studies focus on green exclusively, but there is still limited work that relates sustainability measures and leans for managing and reducing waste. The objectives of this research are: 1) to identify factors that influence the greenness of software based on sustainability measurements and lean, (2) to develop a green software process model based on sustainability measurements and lean management (LeGeS model), (3) To validate and implement the proposed model through expert verification and case study. This research was conducted in four main phases; the first phase was conceptual model design; the second phase was an empirical study which involved interviews. The third phase was developing the Lean-Green Software Process (LeGeS) Model, and the last phase was model validation and refinement. Integrating sustainability measures and lean management offers the potential to develop the software in a greener process. It is beneficial in adding new knowledge and enhancing future software engineering studies.

Keywords: Green Software Process, Sustainability Dimension, Lean Approach, Lean-Green Software

Process Model

1. INTRODUCTION

In the current rapid ICT development, studies have shown that ICT can have a negative impact on the environment. According to Ericsson (2013), the ICT sector has contributed about 2% of global carbon dioxide ($CO2$) emissions, as much as 2% of carbon dioxide ($CO2$) emissions from ICT equipment, services and household electronic goods. And about 8% is a source of electricity usage [11]. Thus, the total electricity consumption in the ICT sector is expected to increase by almost 60% from the increase in the number of hardware and the development of networks worldwide from 2007 to 2020.

Literature study shows that current software-process studies do not focus on integrating sustainability measurements towards achieving green processes. Previous studies revealed that sustainability measurements could be identified as economic, social, environmental, individual and technical. Several works in green software development in general, but not much consideration on embedded green measurements regarding sustainability and improving the greenness process through a waste management approach. Waste management is one of the vital aspects of achieving a green environment [2].

Previous works revealed that waste reduction would improve the efficiency and productivity of work. Initial investigation shows that software processes and waste management are still immature due to a lack of integration between the three fundamental dimensions of sustainability, namely economic, environmental, and social, which later extended to individual and technical aspects. Studies in green hardware with respect to energy consumption, power consumption, waste reduction and disposal can be found. Still, there is a lack of studies on green software, even though it indirectly impacts the environment and the software itself. A few studies touch on green exclusively but are still not integrated with sustainability dimensions and waste management.

In general, waste refers to any activity that uses resources but does not produce value for customers. Waste is also defined as activities that are unnecessary and can add cost or time without being able to add value to the process. Based on Lean principles, the concept of waste disposal in manufacturing, identifying and eliminating waste is related to consumer value. Although Lean principles are usually used in manufacturing, it is seen as appropriate to be adapted in the software development process because it involves people from development to operation and maintenance [22] [4].

2. BACKGROUND STUDIES

The correlation between sustainability and green in software development was revealed through the study by [4], who stated that the environmental sustainability dimension came from the software product development perspective. The perspectives are from the term green software or software greenness. In this context, green means encouraging a green development process. While green abilities are how to improve the software development process, this can be part of the quality issue in software engineering. The software development model is to guide the quality of the development process. Thus, this will also ensure the quality of the software produced. Software Development Life Cycle (SDLC) defines the activities performed at each stage of the development process. The activities are requirements definition, system and software designs, implementation, testing, also operation and maintenance [7]. [3] studied and proposed the adjustment in the current SDLC by suggesting in relevant stages the reduction of carbon emissions, paper usage, and lower power usage. It aimed to build environmentally friendly software, improve the development process, and move towards greener development and sustainable software. The most widely used software development models are Waterfall Model, V Model, Incremental Model, Rapid Application Development (RAD) Model, Agile Model, Iterative Model and Spiral Model. Each model aims to have reasonable quality assurance in the software development process [9].

The GREENSOFT model is a conceptual reference model for green and sustainable software that aims to help developers, administrators and users by creating, using and maintaining the software sustainably [10]. The GREENSOFT model contains four major components, and the first component is the life cycle of a software product. This lifecycle differs from the traditional lifecycle because it has an objective towards sustainability, such as assessing ecology, social and human compatibility, and the overall product economics. This process starts from the initial stage of product development and ends with the disposal and recycling of the product. The second component of the GREENSOFT model is the sustainability criteria and metrics that include metrics and criteria for software quality measurement and allow the classification of criteria and metrics to evaluate the sustainability of the software product. The third component of this model is procedures, which can make it possible to classify that model into software development, acquisition, maintenance of IT systems, and user support. The last components in GREENSOFT model are the recommendation and tools that can support stakeholders to develop, purchase, provide and use green and sustainable software [10][11]. GREENSOFT only covers part of sustainability measures and lacks other essential sustainability measures to ensure comprehensive green measurement towards sustainability software.

Shenoy & Eeretta [8] proposed an enhanced model for the software development life cycle and proposed measurements of carbon emissions of power reduction and paper usage to help organizations move towards greener and more sustainable software development. In addition, through this model, the researcher claimed that electronic waste could be gradually reduced in terms of cost reduction during the software development process in the organisation. Therefore, the products developed are environmentally friendly and give value added to consumers. The model presents the integration of best practices for green software development based on electronic waste and power reduction.

A model for green and sustainable software engineering was proposed by Dick et al. [12] comprising two main divisions: process and lifecycle model as well as guidelines and checklists. The process model served to identify the activities during the software product life cycle and related to the sustainability assessment of a product. Green or sustainable techniques were applied during software product development, administration or operation in providing guidelines and checklists. However, it is unclear how the proposed model's mechanism and measurements have been done.

A literature study has revealed a few existing green software models to achieve sustainability in the software process. However, there is still no relevant model that integrates sustainability and waste management to produce a green software development process. Previous studies found that waste reduction will improve the efficiency and productivity of particular work. This is also applicable to software processes. The fundamental dimension of sustainability is economic, social, and environmental [5][14]. Economic sustainability refers to the wealth creation and asset maintenance process. For the economic dimension, it is stated that for any developed software, the stakeholder or the owner must ensure or guarantee that it is safely invested for the long term and free from economic risks [13] [14]. Meanwhile, social sustainability aims to maintain social capital and preserve the community's unity. Software is created to increase capital value by maintaining social relationships. Community and technical users are the social communities related to software systems [15][16]. Environmental sustainability protects natural resources to improve human welfare. The dimensions of the environment in the context of the software should be environmentally friendly to create, use, maintain and erase with minimal impact. Additionally, the environment can be divided into energy use and resource use.

The literature study too revealed other essential dimensions of sustainability, which are technical and individual aspects [16]. [5] argued that the three dimensions were inadequate and added to the other two dimensions of the individual and technicality of the software system in their proposed model. Technical sustainability means software can be used for a long time even though the requirements change or any other conditions. The individual aspect is regarding maintaining of good attitude for personal development [16]. The software is created and maintained to ensure the enjoyment of developers with their work in individual dimensions. This also concerns appropriate work, skills and experience for the developer throughout their working periods.

Waste is considered something irrelevant to production [17]. Waste management puts pressure and a big deal on society to handle rather than dispose of it. As a result, it will negatively affect human and environmental harmony [18]. Some concepts used in managing software waste are system generation, collection and disposal. The Lean development concept is one possible way to handle and manage waste generated in the software development process [19]. Furthermore, waste formation not only occurs in the form of a solid state. Issues in waste were studied and investigated not only in the manufacturing industry [20] but also in other domains such as construction [21] as well as in software development [22]. Lean Software Development was developed by [23] to adapt to Lean Thinking and Toyota Production System from manufacturing to software development. Lean thinking is the process of identifying and eliminating waste in flow values. The process of identifying and eliminating waste involves three main activities: i) activity that can bring a clear value; ii) activity that does not add value to the consumers but is needed for product manufacturing; and iii) activity that is not valuable to the consumer and no longer required and need immediate removal [24]. The previous study has identified some of the remnants of Lean software development. The identified remnant and waste were partial completion, re-learning, additional features, assignments, delays, task exchange and disabilities [25]. Waste reduction in software development is complicated because of the difficulty in identifying the relevant waste [19]. This is different from the waste produced in manufacturing as it is in the form of physical products. While in the software, it does not exist in a detectable form. An earlier study had identified nine types of waste which could be associated with the software. The types of waste are building up the wrong character or product, overlapping work, reworking, unnecessary complexity, extreme cognitive load, psychological distress, waiting or multiple-tasking, and loss of ineffective knowledge and communication [24]. Further study is required to investigate and link this waste with the software process.

Our research group in UKM has also explored the green concept in software and the green environment. We have studied the green data modelling of quarry environments for STEM education. This work proposed a hybrid model for the green data model to motivate STEM education among school children using quarry environment data [26]. This work collaborates with the Malaysia Mineral and Geoscience Department. Another related work in green software engineering is developing the model of green software products based on sustainability dimensions. This research focused on the green in software products [27][28]. One more related project in the green environment was carried out that proposed a green environment architecture and modelling and the computational model of environment quality measurement to support a sustainable environment and improve the quality of life of the people in the quarry areas in Malaysia [29][30][31].

This research hypothesises that integrating sustainability and lean can achieve the green software process. The research questions are: -

- What are the influential factors toward the greenness of the software process?
- How the lean-sustainability software process can be practised to ensure the greenness of the processes in software development?
- How the lean-green software process can be implemented?

3. RESEARCH OBJECTIVES

The objectives of this research are as follows: -

I. To identify factors that influence the greenness of software based on sustainability measurements and lean.
II. To develop a green software process model based on sustainability measurements and lean approach (LeGeS model).
III. To validate and implement the proposed model (LeGeS) through expert verification and case study.

4. METHODOLOGY

This research was conducted in four main phases, as discussed in the following. And figure 1 shows the flowchart of the research activity.

Phase 1: Conceptual Model Design

The first phase of this research is to investigate further the integration between sustainability dimensions and lean in the software process. The references include the latest journal articles, proceedings, and white papers. This phase aims to identify the type of waste and factors that influence the greenness of the software process from the literature study. It also investigates issues and problems from current literature related to the green software process. This phase's outcome is the Green Software Process conceptual model based on Sustainability Dimensions and the Lean Approach.

Phase 2: Empirical Study

The second phase of this study is to conduct an empirical survey. An interview was conducted involving software practitioners to obtain actual inputs from the industry. To achieve the objective of the empirical study, identified respondents are those involved in the field of software development. Survey interviewees include software practitioners (project leaders, software practitioners & developers) with extensive experience, knowledge and perspectives in software development. During this phase, the interview protocol was designed and constructed based on the literature findings and conceptual model developed in phase one. A pilot study was conducted to test the interview questions and related analysis.

The reliability test of the items in the interview protocol was carried out before the survey. The outcomes of this phase have revealed the factors that may affect the greenness of the software process in the sustainability dimensions, as well as the best practices carried out in the actual software industry environment. The wastes among the practices and processes are also identified and revealed.

Phase 3: Development of Lean-Green Software Process (LeGeS) Model based on Sustainability Dimensions and Lean Approach

The third phase was the development of the proposed Lean-Green Software Process (LeGeS) Model based on sustainability dimensions and measurements. The proposed LeGeS model also embedded waste management based on the Lean concept following input from the theoretical and empirical findings. Relationships between the factors and measurements affecting the greenness of the software process were investigated and modelled to support the model development. The waste and remnants were identified at each phase of software processes and aligned with the sustainability requirements that must be fulfilled. The outcome of this phase is the Lean-Green Software Process (LeGeS) model, Lean-Green assessment instrument and Lean-Green level.

Phase 4: Model Validation and Refinement

The last phase of this research was to validate the LeGeS model. The validation was conducted through expert verification and a case study. Experts in the software development process were identified and invited to review and verify the LeGeS model and the inclusive measurements and components. The verified Leges model was then applied in the real environment, which involved collaborating with the software industry. The review reports were analysed and used to refine the final model.

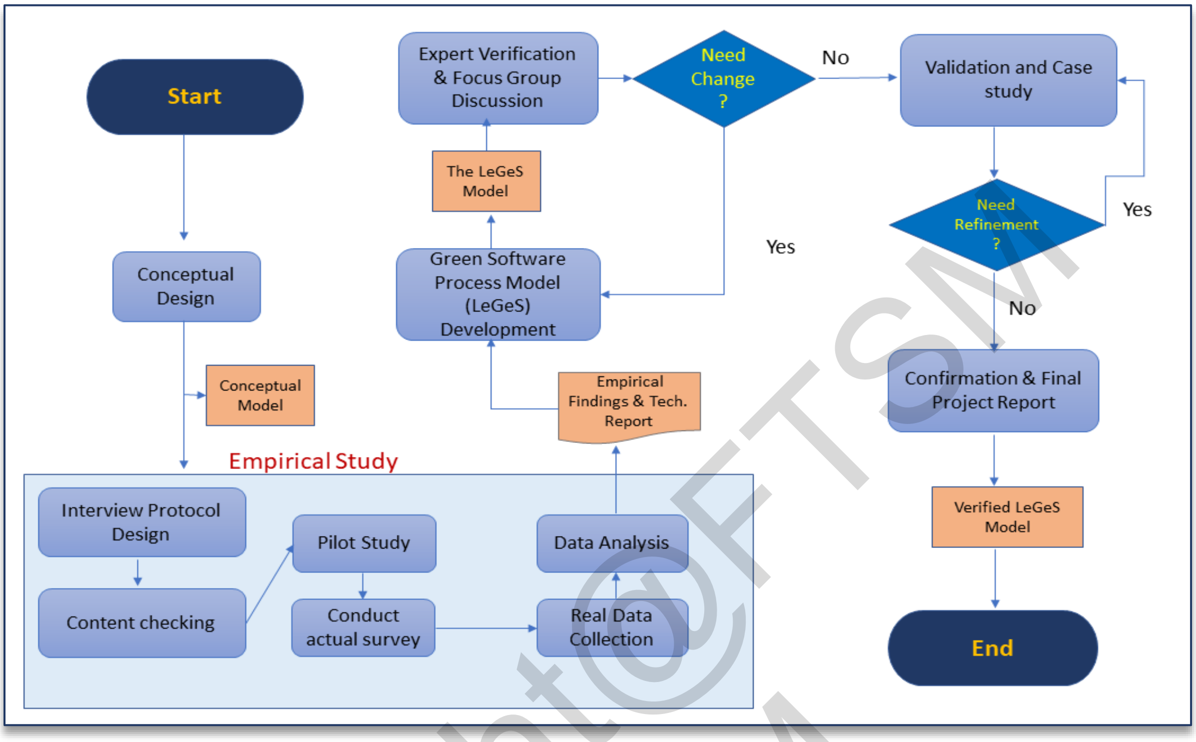

Figure 1: Flowchart of the research activity

5. LeGeS: THE PROPOSED MODEL FOR GREEN SOFTWARE PROCESS

5.1 Empirical Findings

The empirical study carried out in phase 2 has revealed essential and important attributes of green factors and waste. The results from the qualitative study conducted in Malaysia disclosed three main themes: best practices of a software process, nine software wastes and six influential green factors. Nine software wastes were identified: building the wrong feature, rework, unnecessarily complex solutions, extraneous cognitive load, psychological distress, waiting, knowledge loss, ineffective communication, and delay. Six green factors were found: resources, people, organisational, technical, environmental, and technology.

The empirical study has discovered some findings related to best practices of software processes from the industrial point of view. Table 1 demonstrates the findings that show the practices in the software development process.

Table 1: The practices in the software development process: Best Practice, Green Practice and Technology

SOFTWARE PROCESS PHASE	ELEMENT	MEASUREMENT
Requirement Phase	Best Practices	• Software development guidelines and procedures • Brainstorming/Discussion • Two-way understanding (developer and user) • Complete Documentation (URS, SRS) • Prototype demonstration • Continuous/iterative progress
	Green Practices	• Saving (time, transportation, meeting space) • Video conferencing • Time efficiency • Softcopy document • Shared document
	Technology	• Software development tool
Design phase	Best practices	• Software Design Document (SDD) • Database design • Use of appropriate fonts and colours • Use of tabs for extensive paging
	Green practices	• License cost open-source (GNU/GPL) • Open-source software • Appropriate layout & interface • Paper saving • Flexible design
	Technology	• Software development tool
Implementation Phase	Best practices	• Simple programming with object-oriented • Security • API requirements for integration • Expertise and knowledge sharing
	Green practices	• Optimise code • Code refactoring • Code versioning • Inheritance object-oriented programming
	Technology	• Open-source software • Framework technology
Testing phase	Best practices	• User Acceptance Testing (UAT) • Final Acceptance Testing (FAT) • User Feedbacks • Change requests during the testing • Errors discover during testing
	Green practices	• Remote system check
	Technology	• Software development tool

The outcome shows three main elements from the best practices point of view, green practices and technology supported. The main elements are then decomposed into several measurements that could be used to measure or determine the elements. The detail of these findings can be found in [32].

5.2 Model Development

The proposed model was developed based on the input from the previous phase. Three main components of the model were obtained from the literature review findings and then verified by the interview survey. The components are the green factor, waste element and best practices of software processes. Referring to Figure 2, the model also comprises the computational of green and waste scores and the green level component.

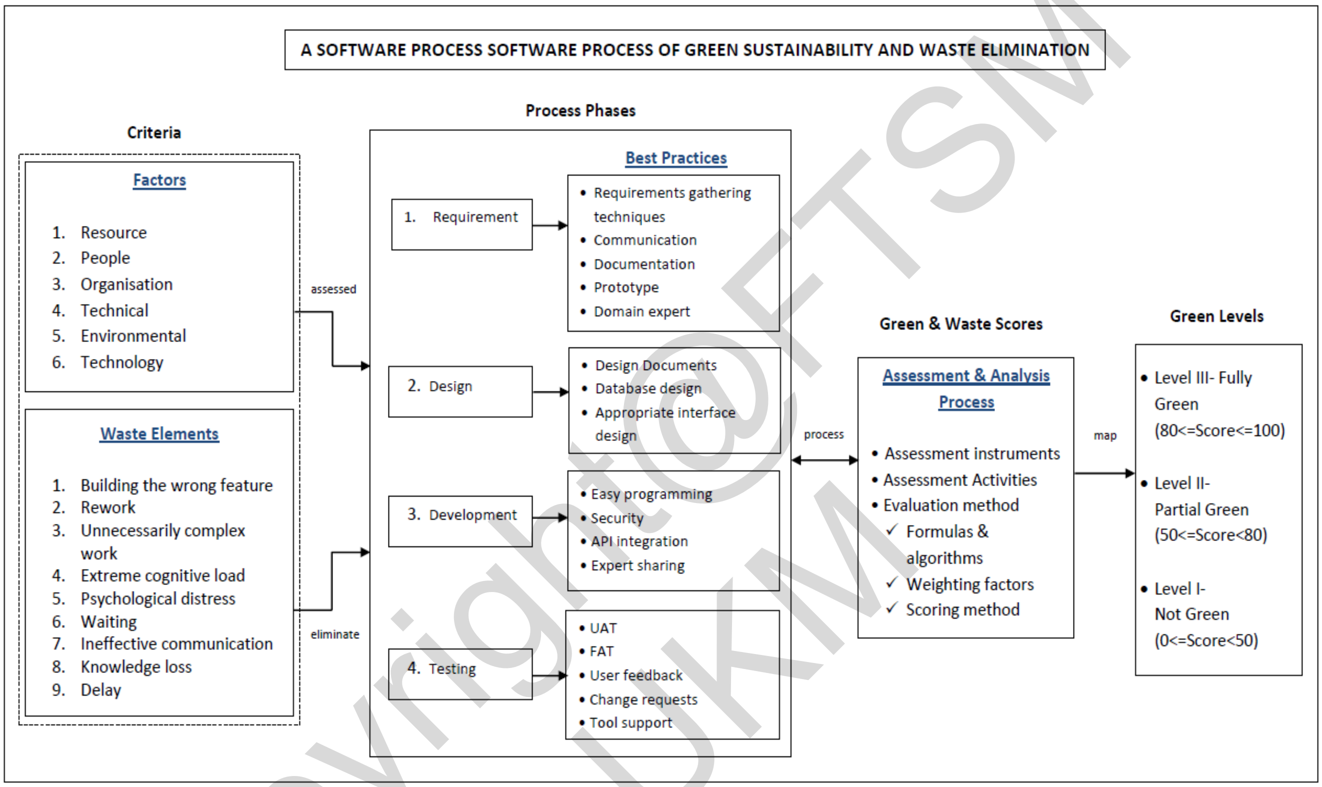

Figure 2: the LeGes Model: The proposed Mode for Green Software Process Based on Sustainability and Waste Management

a) The Criteria - Green Factors and Waste Elements

As shown in Fig. 2, the green factors consist of resources, people, organisation, technical, environmental and technology. Table 2 shows the description of these factors. It describes that regarding a resource, this green factor is concerned with conserving and using resources and energy economically. The people factor measures the role and satisfaction in the software process. The organisational factor means the awareness of green practices at different levels of management and stakeholders. Furthermore, the technical factor measures the ability of the system to be long-lasting with changes in the system's functions, and the environmental factor is used to assess the resources used that do not affect (or have less impact) the environment. The last factor is the technology which refers to tool support and software technologies during the development process. Table 2 summarises the description of green factors.

Table 2: Green factors and description

	Factor	Description
1	Resource	Conserve and use resources and energy economically.
2	People	Role and job satisfaction in software process
3	Organisational	The awareness of green practice at different levels of stakeholders.
4	Technical	The ability of the system to be long-lasting with changes in system function.
5	Environmental	Ensure the resources used are less or do not affect the environment.
6	Technology	The usage of tool support and software technology applied.

The second element in the criteria component is waste. Based on the survey, we have discovered nine waste elements in the software process. The elements are building the wrong features, reworking, unnecessary complex work or tasks, extreme cognitive load, psychological distress, waiting and idle, ineffective communication, knowledge loss and delay [32]. Table 3 summarises the waste elements in the software process.

Table 3: Software Waste Elements

	Element	Description
1	Building wrong features	The developed software is not used.
2	Rework	Re-discussion, requirements are not correctly identified based on the user's need. Rewrite the code.
3	Unnecessary complex work or tasks	The requirement specification document is too complex.
4	Extreme cognitive load	User demand without consideration, additional tasks other than assigned development work.
5	Psychological distress	Burden team members with unhelpful stress.
6	Waiting and idle	Document the requirements of the user; Wait for user testing feedback.
7	Ineffective communication	Misunderstanding of concepts and ideas. Misunderstanding in communication.
8	Knowledge loss	No expertise Take over the work of others (such as the programmers etc.).
9	Delay	Running out of time. Disrupting software delivery

b) Process Phases – Phases of Software Development Process
The second component of this LeGeS model is the best practices in each development process phase. As shown in Table 1, several best practices in the development phases have been discovered and revealed in the survey interviews. The best practices are assigned in each of the software process phases to determine and ensure the greenness of the process. The best practices can be found in Table 1 for detail.

c) Green and Waste Score
The third component is the green and waste score. In this component, the assessment and analysis process will be carried out during the assessment program. The component shows the necessary action in the green assessment program. It requires an assessment instrument, the assessment activity and guidelines and the evaluation method. The evaluation method comprises formulas and algorithms for green measurement, the weightage of the factors and the scoring method.
The synthesis technique used takes into account the removal of software waste. Weights for green factors are determined through model evaluation by experts. The green score is computed using the average score.

d) Green level
Based on the average and weightage scoring method used in part (c), the green level is determined according to the following mapping:-
Level 3 – Fully Green (>=80)
Level 2 – Partial Green (50 <= Score < 80)
Level 1 – Not Green (Score < 50)

5.3 Model Validation

The model validation was carried out in two approaches, expert verification and case study.

a) Expert Verification
The model evaluation and verification form can be found in Appendix A. Five experts were invited to participate in this research and to give evaluation and feedback on the proposed model. The experts verified all the components defined in the model.

b) Case study
The model application through a case study was conducted in collaboration with two agencies in Malaysia. Appendix B shows the instrument for waste identification at the specific organisation, particularly in the software department.

The implementation was carried out in three main phases.

- Pre-evaluation: Evaluation form for the assessor, selecting an organization for the software process, brief briefing about the evaluation process.
- Implementation: Assessor completes the evaluation instrument. The evaluation data is collected through group discussions and meetings, interviews, and document review.
- Post evaluation: Analytical data to determine the degree of the greenness of software processes and generating the report. Presentation of research results to the stakeholders to get feedback for model improvement and verify the assessment report.

Data Collection methods: interviews, group discussion and meetings.

Analysis: The synthesis technique is used to remove software waste in the assessment method and algorithm. Weightage for each green factor is determined through expert's assessment. The scoring method is used to determine the green score and associated green level.

Result for CASE B:

Keputusan status proses perisian **(Kes B)**						
Faktor hijau	**Nilai tinggi (1)**	**Pemberat (2)**	**Skor yang diperoleh (3)**	**Skor yang diperoleh/Bil soalan* skala (4)**	**Skor proses perisian/ Bil soalan (5)**	**Skor hijau (%) (Col 5/ Col 2)*100**
Amalan Proses Perisian		1	19	2.71	0.905	**90.48**
Sumber	3	8	10	2.00	0.667	8.33
Manusia	3	7	11	1.83	0.611	8.73
Organisasi	3	8	7	1.40	0.467	5.83
Teknikal	3	7	5	1.00	0.333	4.76
Persekitaran	3	8	9	2.25	0.750	9.38
Teknologi	3	8	7	2.33	0.778	9.72
JUMLAH	**18**	**46**			**4.510**	**46.76**
Jumlah Skor Sisa						**4.4**

Table 4: Result for Case Study: Case B

The analysis shows the following: -

Total Score for Green Process = 46.76
Green Level = Level 1 (Not Green).

Table 5 shows the result obtained from the case study to show the waste process elements discovered during the software development process. The scale given by the respondents: **5: very often, 4: often, 3: sometimes occur, 2: rarely occur and 1: not occur.**

No.	WASTE ELEMENTS	FREQUENCY OF OCCURRENCE
1	Building wrong features	3
2	Rework	4
3	Unnecessary complex work or tasks	4
4	Extreme cognitive load	2
5	Psychological distress	1
6	Waiting and idle	3
7	Ineffective communication	2
8	Knowledge loss	1
9	Delay	2

Table 5: The waste element frequency of occurrence in the organisation

6. CONTRIBUTION AND FUTURE WORK

This research project has successfully developed and produced a sustainable green software process model and contributes new knowledge in software engineering topics. The model will promote a green process for software development in the organisation and eliminate waste in the work process to create a culture of excellent living in society. The model also supports achieving the mission of shared prosperity as promoted by the government.

7. ACKNOWLEDGEMENT

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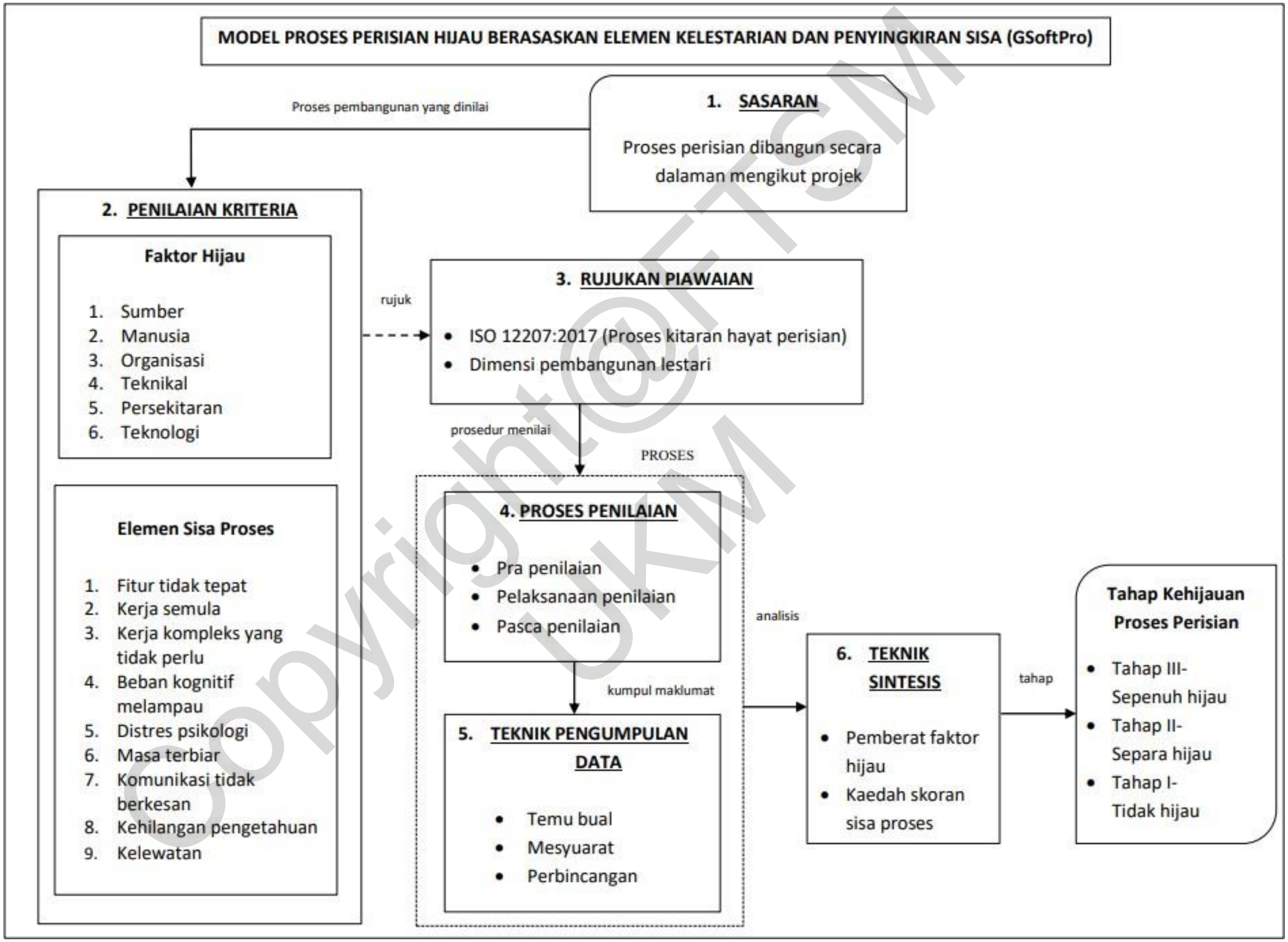
APPENDIX A

BORANG PENILAIAN MODEL GSoftPro

Borang penilaian ini adalah untuk menilai model proses perisian hijau bersaskan elemen kelestarian dan penyingkiran sisa (**GSoftPro)** yang dicadangkan.

Nama Penilai	: ____________________
Jawatan	: ____________________
Organisasi	


MODEL PROSES PERISIAN HIJAU BERASASKAN ELEMEN KELESTARIAN DAN PENYINGKIRAN SISA (GSoftPro)
Proses pembangunan yang dinilai
1. SASARAN
Proses perisian dibangun secara dalaman mengikut projek
2. PENILAIAN KRITERIA
Faktor Hijau
1. Sumber
2. Manusia
3. Organisasi
4. Teknikal
5. Persekitaran
6. Teknologi
Elemen Sisa Proses
1. Fitur tidak tepat
2. Kerja semula
3. Kerja kompleks yang tidak perlu
4. Beban kognitif melampau
5. Distres psikologi
6. Masa terbiar
7. Komunikasi tidak berkesan
8. Kehilangan pengetahuan
9. Kelewatan
rujuk
3. RUJUKAN PIAWAIAN
ISO 12207:2017 (Proses kitaran hayat perisian)
Dimensi pembangunan lestari
prosedur menilai
PROSES
4. PROSES PENILAIAN
Pra penilaian
Pelaksanaan penilaian
Pasca penilaian
kumpul maklumat
5. TEKNIK PENGUMPULAN DATA
Temu bual
Mesyuarat
Perbincangan
analisis
6. TEKNIK SINTESIS
Pemberat faktor hijau
Kaedah skoran sisa proses
tahap
Tahap Kehijauan Proses Perisian
Tahap III- Sepenuh hijau
Tahap II- Separa hijau
Tahap I- Tidak hijau

Bahagian A: Penilaian komponen, faktor dan elemen untuk model GsoftPro

(a) Nyatakan pandangan anda mengenai komponen utama dalam model GSoftPro berdasarkan kriteria seperti berikut:

Bil.	Kategori	Keterangan	Komprehensif	Komen/ Cadangan
1.	Komponen	Sasaran perisian	☐ Setuju ☐ Tidak Bersetuju	
2.	Komponen	Penilaian kriteria (6 faktor proses hijau)	☐ Setuju ☐ Tidak Bersetuju	
3.	Komponen	Penilaian kriteria (9 elemen sisa proses)	☐ Setuju ☐ Tidak Bersetuju	
4.	Komponen	Rujukan piawaian	☐ Setuju ☐ Tidak Bersetuju	
5.	Komponen	Proses penilaian	☐ Setuju ☐ Tidak Bersetuju	

6.	Komponen	Teknik pengumpulan data	☐ Setuju ☐ Tidak Bersetuju	
7.	Komponen	Teknik sintesis	☐ Setuju ☐ Tidak Bersetuju	
8.	Komponen	Tahap kehijauan proses perisian	☐ Setuju ☐ Tidak Bersetuju	

Bahagian B: Penentuan pemberat untuk pengukuran faktor hijau model GSoftPro

a) Nyatakan pandangan anda berdasarkan tahap kepentingan bagi setiap pengukuran faktor hijau seperti berikut:

No.	**Pengukuran faktor hijau**	**Skala Tahap Kepentingan** Tidak penting → Sangat penting									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	**Sumber**										
	1.1 Penjimatan tenaga terhadap penggunaan komputer dan peralatan ICT										
	1.2 Penggunaan perkakasan maya *(virtual machine)*										
	1.3 Perkongsian rangkaian untuk pencetak, pengimbas atau penyalin										
	1.4 Garis panduan perkakasan ICT										
	1.5 Penggunaan sumber digital (salinan lembut)										
	1.6 Amalan 3R (*Reduce, Recycle*, *Reuse*) dalam fasa pembangunan										
	1.7 Penyimpanan storan awan (Google Drive, Dropbox)										
2	**Manusia**										
	2.1 Pembangunan sumber manusia (latihan, *upskilling*, sijil professional, dll)										
	2.2 Kesihatan (kesihatan mental dan fizikal, persekitaran tempat kerja)										

	Pengukuran faktor hijau	Skala Tahap Kepentingan Tidak penting → Sangat penting									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	2.3 Peranan dan sikap										
	2.4 Kepuasan kerja										
	2.5 Motivasi dan anugerah kerja										
	2.6 Kesedaran dan amalan hijau dalam kalangan pembangun										
3	**Organisasi**										
	3.1 Kesedaran amalan hijau dalam organisasi										
	3.2 Penglibatan dan komitmen pemegang taruh dalam pembangunan perisian										
	3.3 Pelaburan dan strategi jangka panjang										
	3.4 Perkongsian maklumat dan sumber (di antara organisasi luar)										
	3.5 Penerapan amalan hijau (hala tuju organisasi, galakan amalan kerja, pengurusan kerja pembangunan)										
4	**Teknikal**										
	4.1 Keupayaan perisian untuk pulih daripada kegagalan mengikut SOP yang ditetapkan										
	4.2 Keupayaan kepada perubahan keperluan baharu										
	4.3 Keupayaan untuk mengubahsuai mengikut polisi dan petua semasa										

	Pengukuran faktor hijau	Skala Tahap Kepentingan Tidak penting → Sangat penting									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	4.4 Penambahan dan pengubahsuaian kepada fungsi perisian										
	4.5 Jangka hayat penggunaan perisian										
	4.6 Keupayaan untuk berintegrasi antara perkakasan (mudah alih)										
	4.7 Kebolehan untuk penghijrahan kepada sistem operasi yang berbeza										
	4.8 Penggunaan sistem pengurusan konfigurasi										
5	**Persekitaran**										
	5.1 Penggunaan platform digital yang bersesuaian (i.e telesidang video, mesyuarat maya, dll)										
	5.2 Sokongan hijau dengan menyingkir sisa proses										
	5.3 Sokongan hijau dengan pengurangan penggunaan tenaga (elektrik dan manusia)										
	5.4 Polisi dan peraturan tentang pelupusan sisa (fizikal dan digital)										
	5.5 Pelaksanaan pelupusan sisa (fizikal dan digital)										
6	**Teknologi**										
	6.1 Penggunaan teknologi perisian										
	6.2 Penggunaan alatan perisian										
	6.3 Pengkomputeran awan dalam fasa pembangunan										

		Pengukuran faktor hijau	**Skala Tahap Kepentingan** Tidak penting → Sangat penting									
	6.4	Sokongan peranti/ media pintar dalam komunikasi berkesan										

SEKIAN, TERIMA KASIH

APPENDIX B

MODEL APPLICATION INSTRUMEN (WASTE ELEMENTS)

INSTRUMEN PENGAPLIKASIAN MODEL (Sisa Proses Perisian)

Nama Penilai : ______________________________

Jawatan : ______________________________

Organisasi : ______________________________

Pengaplikasian model dalam organisasi : ELEMEN SISA PROSES

a) Sila tandakan kekerapan berlakunya sisa semasa proses pembangunan perisian berdasarkan skala yang diberikan.

No.	**Elemen Sisa Proses**	**Skala kekerapan** 5- Sangat kerap berlaku 4- Kerap berlaku 3- Kadang-kadang berlaku 2- Jarang berlaku 1- Tidak berlaku				
		1	**2**	**3**	**4**	**5**
1.	Fitur tidak tepat					
2.	Kerja semula					
3.	Kerja kompleks yang tidak perlu					
4.	Beban kognitif berlebihan					
5.	Distres psikologi					
6.	Masa terbiar					
7.	Komunikasi tidak berkesan					
8.	Kehilangan pengetahuan					
9.	Kelewatan					

Elemen sisa proses	Keterangan
1. Fitur tidak tepat	Membina ciri untuk pembangunan perisian yang tidak memenuhi keperluan pengguna, kehendak dan penggunaan.
2. Kerja semula	Kerja yang dihantar sepatutnya dilakukan dengan betul tetapi ia tidak berlaku
3. Kerja kompleks yang tidak perlu	Penyelesaian kerja menjadi rumit yang sepatutnya dipermudahkan untuk ciri, antara muka pengguna atau kod.
4. Beban kognitif melampau	Penggunaan tenaga mental yang tidak diperlukan.
5. Distres psikologi	Bebanan pasukan dengan tekanan yang tidak membantu.
6. Masa terbiar	Masa terbiar yang tidak diguna dengan sebaiknya
7. Komunikasi tidak berkesan	Tiada komunikasi yang baik termasuklah komunikasi tidak lengkap, tidak betul, mengelirukan, atau tidak cekap
8. Kehilangan pengetahuan	Mendapatkan semula maklumat yang pernah diketahui oleh pasukan itu.
9. Kelewatan	Tugasan tidak dapat dilaksanakan disebabkan oleh kebergantungan kepada tugas lain