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Criteria towards Achieving Sustainable Construction Through Implementation of Environmental Management Plan (EMP)

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Abstract – *Malaysia is experiencing an encouraging socio-economic development, especially in its quest towards Vision 2020 and achieving the status as a developed country. The success can be attributed to the government's efforts and commitment in developing projects, which include the construction of new townships and public infrastructures. Through the implementation of Environmental Management Plan (EMP) during the construction phase, the government has taken great efforts and initiatives to ensure that construction projects are well-developed in a sustainable manner. Unfortunately, these rapid physical developments affect and pollute the surrounding environment, even though EMP is implemented at the construction site. The effectiveness of sustainable construction methods in the plan has been found to be very limited in the actual industrial practice. Hence, this paper aims to determine the important criteria needed to be incorporated into EMP in enhancing and ensuring its effectiveness in managing environmental aspects during the construction stage.*

Keywords: environmental management plan, sustainable construction

1.0 INTRODUCTION

Construction has always been regarded as an essential and important sector in the development process, as well as the growth of a country. Previous studies have found that construction has significant undesirable impacts on land resources and surrounding environment, whether it involves the activity of constructing new structures, repairing or maintenance works [1,2]. The generated impact also affects the associated livelihood in regards to the socio-economic context. Previous research has shown and suggested construction as a sector that causes damage and degradation to the surrounding environment due to erosion and sedimentation, depletion or uncontrolled exploitation of natural resources [2,3], as well as excessive generation of construction waste [1] to fulfill the demand of socio-economic growth.

Physical development comes with a high price to the environment. Even though there are several initiatives to manage and solve environmental problems at construction sites, the best solution to overcome the issue and mitigate the environmental pollution from construction activities has yet to be found. Formulation of policies and appropriate environmental programmes is essential to ensure sustainable implementation of development not only

during the physical construction stage, but also at the beginning or planning stage of the development [4]. The EMP, which is part of the implementation approach in the established policy that usually drafts out essential steps and procedures, together with the management programmes to manage environmental aspects, limits negative impacts due construction activities [5]. Through the implementation of EMP during the construction stage, efforts and strategies have been framed and outlined to ensure that the construction projects are well-developed in a more sustainable manner. However, the effectiveness of sustainable construction methods in the plan has been found to be very limited in the actual industrial practice. Because of that, the objective of this paper is to address the criteria needed towards achieving sustainable construction through the implementation of EMP in ensuring its effectiveness and workability in managing environmental aspects during the stage of physical construction.

1.1 Sustainability in Development

Development is considered as a multidimensional activity that involves multiple disciplines and stakeholders in order to achieve its ultimate goal of improving the quality of life [6]. Sustainable development, on the other hand, is identified as the best solution and mechanism to solve environmental issues caused by the industry [7]. As a subset of sustainable development, the concept of sustainable construction, which is based on three main elements of the environment, social and economic [8], is regarded as the best strategy for tackling environmental pollution caused by construction physical activity. However, the effectiveness of sustainable construction approach is found to be very limited due to some factors such as profit driven and failure to identify and measure the contribution of the project towards sustainable development, especially during feasibility study [9].

Sustainability is an ongoing retention capacity, which is essentially to generate better output, as well as the balance of two main dimensions of environment and human. With due consideration of the aspect of sustainability, economic growth and physical development will also be offset by social welfare and sustainability of natural resources [10]. The issue of sustainability was first debated over recent decades, particularly since the publication of the report 'Our Common Future', where a lot of efforts have been done to translate these sustainability elements into a component that is able to be measured [11]. To realize the concept of sustainability particularly in the construction sector, it may require a comprehensive multi-stakeholder participation and collaboration of different talents, leaderships and also active participation especially from the top management level. As industry is often associated with damages to Earth's surface and contamination of natural resources, the concept of sustainability should be applied and embedded at the early stage of a construction cycle [12].

In order to fulfill the concept of sustainability, especially during the stage of physical development and also in the whole cycle of construction activity in general, efforts in governing the environmental aspects of construction sector have expanded rapidly [13], and the principles of sustainable development have been applied to the entire construction process [14]. As environmental pollution and other issues such as the use of natural resources have become more and more uncontrolled, sustainable construction as a subset of sustainable development has become an important agenda at the local and global levels [15]. The mission of sustainable development essentially requires industry players to practice and apply the sustainability concept accurately in order to improve the quality of environmental management in all sectors including construction [13]. Even though there are several

constraints to implement the concept as once expressed by Ofori [16], however, it is abundantly clear that industrial practices and related policies are capable of running in tandem to meet the demands and needs of theirs [10]. Therefore, the right element and proper guidance should be developed to solve the problems associated with the practice that is adopted and implemented.

Sustainable development has been identified as the best problem solver and as an immediate response towards environmental issues caused by the industry [7]. Clear vision and ultimate objective of obtaining a sustainable development in regards to environmental aspect have resulted in an urgent pressure on industrial players to adopt and perform methods that would enhance the performance of environmental quality across the industries including construction [13]. As the ultimate end users of natural resources, construction sector has been said as one of the major polluters [17] and will always generate undesirable negative impact to the environment [18]. However, in sustainable construction concepts, there are several alternatives and options of best management practices throughout the whole physical process, such as the implementation of resource and energy efficient methods, as well as the adoption of a more sustainable approach for built items. If these methods are being implemented effectively, sustainable construction is more than capable of reducing the generated environmental impacts [18].

Sustainability in construction has become the main topic of the debate among industrial practitioners and researchers since late 1980s [19]. With the enforcement of the Kyoto Protocol that emphasizes on sustainability theme, it has then begun to be acknowledged by engineers [6]. According to Hill and Bowen [20], sustainable construction can be divided into four important pillars that consist of biophysical, social development, economic prosperity and technical principles. The authors have also agreed that practitioners in the industry have to minimize the negative impact produced from development activities, and start to contribute towards enhancing other important aspects, especially social matter. Six important principles to be adopted in industrial activity towards achieving sustainable construction have been introduced by Kibert [21] as follows:

i. To minimize consumption of natural resources.
ii. To maximize the reuse strategy.
iii. To use renewable resources.
iv. To protect the natural environment.
v. To provide a non-toxic surrounding.
vi. To ensure quality in the built environment.

Other scholars such as Zainul Abidin and Pasquire [22] have incorporated seven sustainability principles into construction activities which include:

i. Ensuring the health and safety.
ii. Safeguarding the interests of future generations.
iii. Evaluating the costs and benefits of the project towards society.
iv. Limiting environmental pollution.
v. Enhancing the quality of development.
vi. Utilising technology and expertise.
vii. Complying with rules and regulations.

Apart from the efforts towards realising the green agenda in the industry, other efforts such as training, awareness and knowledge-sharing are also of paramount importance in realising sustainability concept in the industry [8], which will then attract interests and demands of the industrial practitioners, and thus, will indirectly smoothen the implementation.

1.2 Implementation of Environmental Management Plan – A Strategy towards Achieving Sustainability in Construction Practices

Effective planning and management of the environment are critically important to identify relevant environmental aspects of the project, to investigate existing risks, and also to formulate the steps and preventive actions to mitigate the negative impacts from entering the surrounding environment [23]. An EMP contains the framework for the preparation of construction environmental management and also the measures to mitigate generated on-site negative impacts towards acceptable limits. The plan is also regarded as a living document as it shall be revised and improved when it is required throughout the implementation stage of physical constructions. With effective execution, the plan is expected to mitigate and reduce adverse impacts from the development site and will ensure usage efficiency of its natural resources. One of the main contents of the EMP is the environmental monitoring programme, which outlines steps and procedures for monitoring activity, location of monitoring, parameters involved and also the explanation of laboratory analysis from the monitoring results.

Adoption of voluntary management system of ISO 14001 is also capable of driving the industry towards a better environmental performance [12]. The system enables an organization or the project proponent to set the goals, monitor the performance and establish the decision on when to take the corrective or preventive action. Incorporating the ISO system as part of the implementation will provide a platform for the organization towards managing their environmental aspect systematically [23], and this will greatly improve their environmental performance [24], especially during the physical construction stage.

1.3 Malaysia's Efforts in Enhancing Sustainability in Construction Industry

The Malaysian government is fully committed to fulfill its sustainable development ambition and agenda. This sustainability agenda is clearly and specifically addressed in relation to the issues caused by the construction or building sector. As the country aims to achieve a developed country status by 2020, popularly known as Vision 2020, the government expects the construction or building sector to play a major role [8]. In ensuring successful implementation of the government's development projects under the five-year Malaysian Plan, Public Works Department (PWD) as the government implementing agency has been given the full authority and responsibility to implement all the well-planned projects. PWD is involved right from the project inception phase, followed by the planning phase, the physical construction phase, as well as the handing over and maintenance stages. In ensuring sustainability concepts are being embedded during the planning stage and good environmental management is being practiced during the physical construction stage, PWD has formulated and implemented "Green Mission", which is in line with the national aspirations. With the accreditation of the Malaysian Standard (MS) ISO 14001 since 5th November 2002 [25], the department will ensure that all proposed development projects are being implemented in a more sustainable manner.

As part of the contractual agreement with the nominated builder or contractor, environmental protection works are carried out to minimize the negative impacts on the environment through the implementation of EMP in most of the development sites. Due to recent rapid development projects stated under the Malaysian Plan, the concept of environmentally sensitive areas has also been introduced and adopted prior to any development. Under this concept, the relevant area will be prohibited from any type of development. Based on its terrain, nature and functionality, the area can be grouped into three categories; protection of biodiversity, life support system and hazard risk areas. As linear construction project such as road and highway development, or even the more centralized type of construction including development of new township frequently involves the cut and chop through green and hilly areas, the Malaysian government had taken immediate action with the establishment of the National Forestry Act (NFA) in 1977 [25].

Professional bodies and institutions of other related technical disciplines are also actively involved in realising and embedding sustainability concept in their day-to-day tasks and development practices. A good example is the Green Building Index (GBI) introduced by the Board of Architects Malaysia, which focuses on the matter of water and energy saving, as well as indoor environment. Under the authority of the Ministry of Works, the Construction Industry Development Board (CIDB) has been established to lead, review and expand the construction industry. CIDB leads the task in enhancing the construction sector, which also includes the sustainability theme of the development agenda. One of the highlighted efforts was the introduction of the Construction Industry Management Plan in 2006 with its main objective of encouraging the application of sustainable practices among engineers throughout their day-to-day technical task and also generally throughout the cycle of the construction project itself [2]. Apart from the plan, there are also collaborations and co-operations that took place with academicians or researchers from local universities and industrial experts, which involved assessing and reviewing workflow and processes during the construction project, construction material and methods, as well as technical procedures in construction cycles.

1.4 EMP Practices in the Malaysian Construction Industry

Referring to the policy in developing the framework for environmental management works, Environmental Impact Assessment (EIA) and EMP are regarded as part of the implementation approaches particularly during the construction stage in the project development cycle [5]. In Malaysian construction industry practices, EMP contains the framework for site environmental management during the physical construction stage. This plan also contains the proposed mitigation measures which include the technical design and drawing, location of the measures, monitoring plan and schedule, the work flow or process for emergency response plan, list of relevant rules and regulations, and also environmental audit. In accordance to the management plan, the proposed mitigation measures shall limit the on-site environmental impacts to the acceptable limits as stipulated by the Department of Environment or any other related department where applicable.

With the certification of ISO 14001 and the implementation of EMP, various site environmental management and surveillance activities including environmental audit and inspection, together with environmental quality monitoring, are being enforced during the construction stage. In any development project, before the commencement of any physical work at site, the contractors or developers need to submit the EMP document, which is initially prepared and compiled by a nominated registered environmental consultant. This

document has to be approved prior to any physical work at the construction site. The EMP shall be submitted to the Public Works Department for endorsement within a period of 45 days from the date of nomination of the successful contractor or bidder, or the date of issuance of the Letter of Acceptance to the contractor [25]. The EMP shall comply with the requirements as stipulated in the contract or relevant law and regulations if the project site is subjected to the requirement of EIA.

The establishment of environmental monitoring program as part of environmental management activity is very important as stipulated in the EMP document for construction project. The monitoring activity will indirectly check, inspect and audit the workability of the proposed mitigation measures at the construction site and will serve as a feedback tool on the effectiveness of the environmental protection set-up at the working site. It is a periodical inspection of the environmental indicators that evaluates the environmental performance through comparisons against the baseline and compliance levels. The parameter, location and frequency of the monitoring are subjected to EIA approval conditions, or shall be proposed by the environmental expert or consultant. An accredited laboratory shall then conduct the monitoring and analyse the samples before reporting it back to the environmental consultant or supervision engineer at site for further action. As part of the management task stipulated in the plan, periodical environmental quality report is published. The report contains the condition of environmental performance concerning air and noise quality, together with water quality, marine life and other relevant environmental aspects.

2.0 RESEARCH IMPLEMENTATION METHODOLOGY

Design and research implementation methodology is a very important element in a research. A collection of good data will be obtained from a well-planned study based on a proper and suitable design [26]. Given that this research aims to recommend the criteria to be associated with the EMP to enhance and ensure its effectiveness in managing the environment, hence qualitative research has been selected. Although quantitative research is more relevant and synonymous with engineering research, however qualitative research has also been used in the fields of construction and engineering study, for example the research conducted by Lenferink et al. [11].

2.1 Literature Review

Literature review was conducted at the beginning of the study to gain better understanding of sustainable development concept and sustainable construction as its subset. Additionally, it also seeks to obtain keywords to determine the search category for sampling of articles and data collection during the content analysis. At the initial stage, electronic literature review was conducted and then followed by research papers and reference materials that are appropriate during the next stage. The data from the research papers were cited before performing further qualitative analysis. The search for articles or research papers has been carried out through online research platforms such as Scopus and Thomson Reuters (formerly known as ISI) Web of Knowledge. The search was conducted through the title or abstract of the paper using a combination of relevant search keywords such as "sustainability", "sustainable development," "sustainable construction" and "construction environmental management". This method had been previously implemented by Simou and Koutsogeorgou [27] in their study that examined the impact of economic and health crisis towards the health industry in Greece, where the literature review was their main research methodology.

2.2 Content Analysis

Content analysis is a method used in research that covers various fields [28] and applications that are widely used [29]. Content analysis has several advantages, which include sensitivity to the text content of a document or a report [28]. Its applicability covers diverse areas such as business policy and strategy, organizational and managerial cognition, research methods, organizational behavior, human resources, technology and innovation management, international management and organizational theory [29]. Content analysis is also widely accepted in the field of communication and information science [30], and also applied in environmental research [31]. Although it is rarely applied in engineering-related research, but it can also be implemented in one, such as the study that was conducted by Gangolells et al. [32], which predicted environmental impacts at the site by the construction works involving local authorities. Another example is the research conducted by Smith et al. [33] to identify key processes in engineering system for the development of the air force laboratory, which is then compared based on the content analysis of literature.

2.2.1 Sampling of Articles

For the purpose of sampling of articles, this study has adapted and modified the procedure used in the study by Duriau et al. [29]. In his study, the search for articles was based on the use of two keywords, and the process involved two main stages, which started with the use of the subject search platform and followed by the review of the list of references at the end of articles. For this study, the survey for comprehensive articles, especially those containing themes of sustainable construction in relevant journals, was done through the search platform of Scopus and Thomson Reuters (formerly known as ISI) Web of Knowledge. Two keywords were used, namely sustainable development and sustainable construction, which have been obtained through the literature review process from the previous stage. As suggested by Duriau et al. [29], the second stage involved a review of the list of references at the end of articles that have been identified. With this method, articles of additional related studies were also available to be used for the analysis. In total, 98 articles from 40 publishing journals have been identified. The journals are listed in **Appendix A.** The articles obtained by the two-stage sampling approach have provided a comprehensive database for the purpose of content analysis.

2.2.2 Data Collection

For the purpose of data collection, the method adopted by Altaweel and Bone [31] was modified. Based on their previous research, the collection of data began by identifying the terms or keywords that were often used in water quality reports provided by Nebraska's Department of Natural Resources, which aimed to facilitate the process of data mining and analysis at the next level. For this study, as it has been implemented during the article sampling earlier, keywords have been identified based on the literature review process at the initial stage. The appropriate keywords (sustainable development and sustainable construction) which have been identified were used as the input or deductive search code for further analysis. Based on the domains for sustainable construction consisting of environmental protection, social development and economic growth, the next stage involved the search for common terms and concepts. This search was intended to highlight the specific terms that would be used in the search category. The search category was used in this content analysis process, as it provides a broad descriptive concept where appropriate terms could be combined.

Content analysis began by identifying the unit of analysis in the text body of the articles, which are in the forms of recording and context units. According to this study, recording unit is a specific concept that exists in the sections that are analyzed in the referenced source, and context unit is a larger and broad content in the same source material. The topics and terms which are interrelated and often relevant to each other were observed in the analyzed sources. The frequency of related used terms were noted, and they were then selected and placed in a category that describes these terms more common, for example, in this study, the search category "management system" for terms such as ISO (International Organization for Standardization), OHS (Occupational Safety and Health) and EHS (Environmental Safety and Health) have been used. The study also referred to the guidelines of the ICC Business Centre for Sustainable Development, which highlighted sixteen environmental management principles for the formulation of the search code to suit the objective of this study. This approach had been used in previous research by Jose and Lee [34].

2.2.3 Data Analysis

In general, the process of data analysis was done in stages, which was started with explicit content analysis (manifest content), followed by the text content that could be obtained directly, and then continued with the approach of implicit content (latent content). It is compatible with the recommendations put forward by Bryman [35], *"... while collecting raw data, analysis involves not only the explicit content (manifest), but also involves the implicit content (latent) to explore deeper meaning of all questions…"*. In addition to the use of deductive search code, inductive approach was also applied during the search process. If the deductive approach is based on research questions, concepts or guidelines, the inductive approach however is not based on any theory or concept, but it is a totally new search code which is identified as a result of the review of the unit of analysis. The approach that considers the implicit content which requires interpretation of the hidden meanings of the text and semantic relations approach, which is the method used by Altaweel and Bone [31], has also been applied to the study. Regarding the semantic relationships that were formed in this study, for example the primary text search for terms such as "non-compliance", the terms were found to be often used in conjunction with other terms known as secondary terms (for example water pollution, water quality and noise). The link or relationship that is developed between these terms indirectly provides a background associated with the key terms. By applying this approach, the total number of terms can be grouped into a single category of smaller and accurate quest, which indirectly limits the potential of 'noise', and assists the search process to be more focused on the categories considered [31]. Thus, according to the two-stage processes; deductive and inductive search codes, together with the application of relationships that exist between terms which had been found, the identification of criteria could be well implemented to achieve the objective of the study. Based on the keywords of sustainable development and sustainable construction together with its respective domain of environment, social and economic, as well as sixteen environmental management guidelines suggested by the ICC Business Centre for Sustainable Development [36], the analysis process was performed on the articles that have been sampled using the search process.

2.2.4 Codebook for Criteria

A code was used as a marker to label the segments of text content, where the issues had been discussed. This codebook contained a list of codes that had been used with the definition, as well as the examples of resources being referred to.

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2.2.5 Use of Software

The use of software for text analysis improves the methodological aspects of content analysis [29]. There are many word processing programs which can be used for some types of data analysis, such as directions "*to find"*, have the ability to find numerous passages in the text that contains the keywords specified [37]. There are numerous examples of computer programs particularly for qualitative research including Mendeley, ATLAS.ti, and NVivo that will assist in identifying the words or phrases as specified by the user. For the coding and search purposes, this study used ATLAS.ti, which appeared to have a lot of assistance during the process of content analysis. Based on previous research conducted by Hamid et al. [38], the encoding process can be simplified using this software. This software has been proven to be very flexible, which enables the search code to be manually created, as well as the automatic options.

2.2.6 Data Quality Control

For the purpose of ensuring the reliability and validity of the data, the method used by Jose, and Lee [34] had been implemented for this research. Based on the method performed, one of the researchers acted as the primary coder while other researchers made random checks to ensure reliability and validity. However, for this research, a modification was done, as only one researcher was directly involved with this research. However, the implementation of this study was supported by other research assistants whose role was to make random checks of the materials analysed.

3.0 RESULTS AND OBSERVATIONS

List of codes (search categories) that have been used together with definitions and examples of data obtained are summarized in **Appendix B**. The search categories identified at the initial stage of data collection are applied as follows:

- "Management system" for terms such as ISO (International Organisation for Standardisation), OSH (Occupational Safety and Health), ESH (Environmental, Safety and Health) and EMS (Environmental Management Systems),
- "Key resources" for terms such as water and energy,
- "Supervision" for terms such as monitoring and environmental management,
- "Conservation" for terms such as forest, ecology, heritage and special-interest, and
- "Institutional" for terms such as stakeholder, commitment and professional.

By using these five search categories, 42 criteria for sustainable construction have been identified, in which the criteria were then categorised under three domains namely environment, social and economic that are consistent with sustainable development concept. The list of 42 criteria is as shown in **Appendix C.**

4.0 DISCUSSION

Physical development is often associated with the construction sector, which is seen as a key contributor to the realization of development agenda. As a subset of sustainable development, sustainable construction which consists of three major domains of environment, social and economic is regarded as the best approach for construction industry to achieve its sustainable development objectives. Elements of environmental protection, social development and economic growth which are integrated under this concept have enabled the industry practices to be more sustainable in nature, as the construction sector is often seen as the main cause of damage and destruction to the environment and natural resources. The principles of sustainable construction should be applied to the construction process, and it should begin as early as during the planning stage until the end of the physical construction and maintenance stages.

From the results of the initial literature review and followed by the implementation of content analysis, a total of 42 criteria for sustainable construction were identified. These criteria are seen as important and critical to ensure effective management practices, especially those involving environmental aspects at construction site. All 42 criteria that were identified could be categorized under three main domains based on the key elements of sustainable development. This study suggests that the criteria to be considered and incorporated into the EMP to ensure that the ultimate goal of sustainability to conserve and protect the environment and natural resources can be realized successfully and effectively. In ensuring the balance of these three domains is achieved, the criteria also include community or social aspect as an important element to meet the sustainability agenda during the development process. Similarly, the economic domain is not left behind, which needs to be addressed to ensure that the overall physical development agenda is a well-balanced process.

5.0 CONCLUSION

Several criteria need to be considered and incorporated in ensuring effective implementation of EMP for the purpose of practising and achieving sustainable construction. As sustainable construction is the subset of sustainable development, the aspects of environment, social and economy shall become the pillar of effective implementation of EMP. With the ultimate objective of sustainable construction, which is to achieve the highest standard of environmental performance for all activities, this may require several criteria that need to be incorporated and adopted to ensure better environmental performance for the construction project. 42 criteria have been identified for this purpose, which can be categorized into three main domains based on sustainable construction pillars. The environmental aspects identified include waste minimization, adoption of recycling, water saving, effective energy consumption, minimization of non-renewable resources, and pollution prevention as part of the criteria for environmental protection. In addition, social development and economy aspects are also critically important in balancing the sustainability theme, as the identified criteria under these dimensions will indirectly drive a better and effective management for a healthier built environment, which is also dependant on the ecology and resources principles. To ensure the current construction practices can be improved, therefore the criteria proposed should be given due consideration by the project implementer or the project manager in their EMP. With the ultimate goal of the EMP to achieve good environmental quality in the construction activity, which also includes the environmental design, physical construction, and implementation of relevant programs, then these suggested criteria should be taken into

consideration into any proposed development to ensure that the sustainability objective and agenda are successfully fulfilled and materialised.

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Appendix A - List of Journals

1. Recycling
2. Resources and Conservations
3. Habitat International
4. Journal of Cleaner Production
5. Global Environmental Change
6. Automation in Construction
7. Safety Science
8. International Journal of Production Economics
9. Renewable and Sustainable Energy Reviews
10. Environmental Impact Assessment Review
11. Ecological Economics
12. The Science of the Total Environment
13. Environmental Impact Assessment Review
14. Environmental Development
15. Procedia Engineering
16. International Journal of Project Management
17. Waste Management
18. Renewable and Sustainable Energy Reviews
19. Asia-Pacific Chemical
20. Procedia - Biological & Environmental Engineering (APCBEE)
21. Social and Behavioral Sciences Procedia
22. Building and Environment
23. Computers, Environment and Urban Systems
24. Environment, Development and Sustainability
25. Journal of Energy
26. Journal of Environmental Economics And Management
27. Environmental Pollution
28. Journal of Environmental Management
29. Cities
30. Transport Policy
31. Renewable and Sustainable Energy Reviews
32. Environmental Engineering and Policy
33. Sustainable Cities and Society
34. Procedia - Social and Behavioral Sciences
35. Journal of Purchasing and Supply Management
36. Australian Journal of Management
37. Ecological Indicators
38. Architectural Engineering and Design Management
39. Landscape and Urban Planning
40. Accounting Forum

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Appendix B – The Codebook for Sustainable Construction Criteria

No	Search category	Highlighted criteria	Example of Resources from Literature
1	Management system	NCR	The results of the external audit consist of a report containing opportunities for improvement, observations and non-conformities. Regarding the non-conformities, the firm resolves them with preventive and corrective actions [39]
2	Management system	EMS	Environmental Management System (EMS) has been recognized as a way to achieve sustainable development in the construction industry [40]
3	Key resources	Energy consumption	Energy is at the centre of the sustainable development paradigm as few activities affect the environment as much as the continually increasing use of energy [41]
4	Key resources	Water saving	The post-project analysis of ecological impacted construction projects shall put priority on the medium- and large-sized construction projects in the sensitive regions of ecology such as natural reserves, drinking water sources, and scenic spots as well [42]
5	Procurement	Less toxic	For civil engineering constructions, the use of harmful materials and substances during construction works and maintenance, transport during construction and the use of energy during maintenance have been identified as the most important environmental aspects [43]
6	Institutional dimension	Professional	The effectiveness of these measures can only be realized if all construction professionals participate in applying them [13]
7	Procurement	Sustainable procurement	By determining sustainable qualification, award and contract performance criteria that link the early plan development and design activities in public plan-making to the design activities in contract implementation, green procurement can provide private market parties with public wishes and ambitions for later stages that exceed standard project preconditions [11]
8	Supervision	EIA	An appropriate EIA follow-up system should comprise of an environmental monitoring plan prepared by the EIA consultant and compliance monitoring consisting of regulatory and impact prediction audits prepared and implemented by the authority [44]
9	Sustainable procurement	Technology transfer	The lack of mature green technologies presents a significant barrier for green construction [45]
10	Supervision	Measurement and reporting	The main objectives of monitoring activity include the organization and interpretation of the environmental monitoring data to establish a record of change associated with the implementation of a project or the

			operation of an organization [44]
11	Supervision	Waste minimisation	It is, thus, agreed that the process of waste minimization must be started at the early stages of the project [46]
12	Institutional dimension	Multi-disciplinary	Any company or organisation seeking to improve their environmental performance should engage in the development of collaborative partnerships with the like of government, NGOs, customers, and suppliers aimed at sharing complementary knowledge and capabilities or developing new ones [47]
13	Conservation	Future changes	In that case, the surrounding community may regard environmental impact (landscape alteration by the presence of singular elements) as a highly significant environmental impact. The significance of this environmental impact decreases if the construction site is located in an urban area without nearby historical/artistic buildings or in a rural area not registered as a special-interest area [32]
14	Management system	Less complaints	… they have to explain how they involve residents and interest groups during the construction and maintenance stages. They feel that this attention to the relation with the environment helps in raising public awareness and thereby limits the number of complaints [11]
15	Institutional dimension	Training	Environmental training is fundamental to any successful activity of environmental management, conservation and recycling of resources [48]
16	Management system	EMP	Every business requires some type of loss and pollution prevention program that will vary with individual needs but some conscious planning effort is always necessary. Secondly, since not all environmental pollution and damage can be excluded, it is necessary to prepare for necessary treatment actions [49]
17	Institutional dimension	Top level commitment	If owners consider and require construction project works from a perspective of sustainable development, the real driving force can be gained to achieve better sustainability [9]
18	Supervision	Recycling	As in highway construction, recycled products have thus emerged as a viable alternative to virgin materials in the highway construction sector [50]
19	Key resources	Avoiding CFC	Another environmental priority set up by the Sixth Environment Action Programme is health and quality of life. Therefore, the environmental impact such as emission of VOCs and CFCs should be considered to have outstanding significance [32]
20	Conservation	Biodiversity and ecological	In this type of linear engineering project, where the possibility for development confronts conservation

		protection at site	interests, it should be pointed out that among the priorities of the constructors and operators is the concept of security, along with a consideration of the technical and economic difficulties, whereas for the environmental experts, the idea of conservation prevails: the maintenance of the ecological processes that guarantee the stability of the landscape [51]
21	Conservation	Biodiversity and ecological of surrounding area	However, if the affected area is located outside the construction site perimeter, it cannot be assumed that it will be restored, and the resulting environmental impacts may, therefore, have greater significance [32]
22	Sustainable procurement	Environment friendly design	Design documents have great influences on the sustainable performance of construction projects. Designers and engineering consultants should be consulted in the feasibility stage for professional advice on various alternatives and their influences to the project sustainability [9]
23	Institutional dimension	Appropriate organizational and process	… sustainable construction practices include five major areas: compliance with sustainability legislation, design and procurement; technology and innovation; organizational structure and process; education and training; and measurement and reporting [14]
24	Management system	Disaster management	It is of great importance to analyze the vulnerability of different regions to enable the government to make policies for distributing relief funds and help the regions to improve their capabilities against disasters [52]
25	Supervision	Preventing pollution	Contractors play an important role in promoting sustainable development within the context of the construction industry by assuming the responsibility to minimize their negative impact on environment and society and maximize their economic contribution [14]
26	Key resources	Non-renewable resources minimised	The key priorities of such an energy policy, must be to reduce fossil fuel use, move away from nuclear power, improve the efficiency with which energy is used and increase the amount of energy obtainable from sustainable, renewable sources [53]
27	Management system	Voluntary system	Worldwide, several laws have been created or amended to facilitate the management of OHS in the workplace, together with the integration of OHS risks into the project management and industrial safety [54]
28	Management system	Effective feedback-loop	Project risk management is the process concerned with identifying, analyzing and responding to project risk, which consists of activities that include risk identification, risk quantification, response development, and control [55]
29	Management	Platform for	The experience related to practice in carrying out

	system	public	project-level EIA has demonstrated that some environmental aspects may be neglected even though the directive requires their consideration in the assessment process. Socio- economic impacts, e.g., are often largely overlooked as developers have chosen their own interpretations of what they have to do to consider impacts on ‘‘human beings.’’ [56]
30	Conservation	Relocation of orang Asli	The right of indigenous peoples to be involved in environmental management of projects that affect them has won increasing recognition in international conventions and in the policies of national governments and international institutions [57]
31	Management system	Risk consideration	In relation to construction activity, with a proper implementation of assessment it will assist a construction company in dealing and assuring their health and safety risks and improving their performance, as with a safer and conducive working environment will indirectly increase workers' performance at workplaces which will also increase the productivity of the project [58]
32	Management system	Response and plan for rebuilding process	But when the impact of natural disasters on regional development is concerned, the frequency of the disasters or absolute loss becomes the main consideration, while the differences in long term capability to recover among regions at different levels of economic development are ignored [52]
33	Management system	Safety and health	Through proper health and safety assessment implemented on construction project, it will assist a construction company in dealing and assuring their health and safety risks and improving their performance [58]
34	Management system	Reduction of accident	On-site incidents, accidents and potential emergency situations may also raise concerns amongst immediate neighbours. Indeed, environmental impacts (fires at areas for storing flammable and combustible substances, breakage of underground pipes, and breakage of receptacles with harmful substance, which are refer to events that go beyond the physical boundaries of the construction organization [32]
35	Management system	Effective communication and reporting	Communication is especially critical for the green project in order to convey the sustainable practices expected from the team members [55]
36	Supervision	Good housekeeping	Pedestrians may also be bothered by the dirtiness of construction site entrances. The significance of environmental impact (operations that cause dirtiness at the construction site entrances) may vary depending on whether the construction site is located in an urban area and whether it is located on a low-,medium-or high-traffic road [32]

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37	Key resources	Water and sanitation	The environmental impacts related to soil alteration such as; use of concrete release agent at the construction site, use of cleaning agents or surface-treatment liquids at the, dumping derived from the use and maintenance of construction machinery, dumping of water resulting from the execution of foundations and retaining walls, dumping of water resulting from the process of cleaning concrete chutes or dumping of other basic fluids and dumping of sanitary water resulting from on-site sanitary conveniences also depend on the sensitivity of the receiving environment. These environmental impacts should be found to be more significant in construction projects located in rural areas near water courses, areas with legal protection or other areas that, due to their unique nature, must be specially protected [32]
38	Conservation	Consideration of heritage	Another aspect which also vital in balancing the pillar of sustainable development is heritage conservation, recognized as an inherent development tool [59]
39	Sustainable procurement	Erosion and sediment control plan	… even high potential soil erosion that may have different consequences depending on the location of the construction project [32]
40	Sustainable procurement	Cost for environment protection work	For example during the procurement process, as been commonly perceived that the cost increase and resources consumption will be unavoidable from implementing environmental management, no measures will be effectively received without the enforcement and supports from government [13]
41	Supervision	Fines and penalties imposed	In implementing environmental management, the benefits to contractors can be in a number of ways, for example, cost savings due to the reduction of fines associated with convictions as a result of complying with environmental legislation [13]
42	Supervision	Regulatory compliance	It is recommended that the critical role of green construction and sustainable development is specifically highlighted in the fundamental legal system of the construction industry [44]

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Appendix C- Identified Criteria for Sustainable Construction

Environmental Domain	Social Domain	Economic Domain
Number of NCR	Voluntary system	Effective and economical~ planning and design
Environmental Management System of ISO 14000	Effective feedback-loop	Cost for environmental protection works
Energy consumption	Platform for public	Fines and penalties imposed
Water saving	Relocation of Orang Asli	Regulatory compliance
Less toxic	Risk consideration	
Qualified professional	Response and plan for rebuilding process	
Sustainable procurement	Safety and health	
EIA compliance	Reduction of accidents	
Technology transfer	Effective reporting	
Measurement and reporting	Good housekeeping	
Minimum waste	Water supply & sanitation	
Multidisciplinary involvement	Consideration of heritage	
Future changes consideration		
Less complaints		
Training and awareness		
Environmental Management Plan (EMP) revised		
Top level commitment		
Recycling adopted		
Avoiding CFC		
Biodiversity & ecology protection at site		
Biodiversity & ecology protection of surrounding area		
Environment-friendly design		
Appropriate organizational structure and process		
Disaster management		
Preventing pollutions		
Non-renewable resources minimized		