ADOPTION OF ECO-COSTS PER VALUE RATIO CONCEPT IN CONSTRUCTION WASTE MANAGEMENT

SHARAN KUMAR S/O ARUMUGAM

A dissertation submitted in partial fulfilment of the
requirements for the award of the degree of
Doctor of Engineering Specialization Engineering Business Management

Razak Faculty of Technology and Informatics
Universiti Teknologi Malaysia

DECEMBER 2022

DEDICATION

This dissertation is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

ACKNOWLEDGEMENT

In preparing this dissertation, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my main thesis supervisor, Dr Rahimah Muhamad, for encouragement, guidance, critics and friendship. I am also very thankful to my co-supervisor Dr Khairulzan Yahya for his expertise this the field of study, guidance, advices and motivation. Without their continued support and interest, this thesis would not have been the same as presented here.

My fellow engineering doctorate students should also be recognised for their support. My sincere appreciation to also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space.

I am grateful to all my family member. Especially my wife Dr Swarnamugi for her morale support to keep me pushing towards the goal that has been set for. Without her mental and physical support, I would not complete it within the time frame given. Finally, my parents for their continues encouragement and prayers.

ABSTRACT

The rapid growth of Malaysia's construction industry contributes indirectly to the growth of the economy. With the increase in new building technologies, waste production in construction is rising proportionally. The current construction practices focus on a limited recycling mechanism in which most building waste is discarded at landfills. This is due to the higher preliminary costs for proper waste disposal that must be borne by construction companies. Case studies on implementing Eco-costs per Value Ratio (EVR) index in waste management based on suitable residential projects within the perimeter of several influencing factors are still lacking. Hence, the aim of this study to further explore on the use of EVR in managing construction waste produced from sites. The approach used was close monitoring using Google My Maps, Appsheet and spreadsheet. The cost of disposing off the construction waste from its generation at the initial stage can be reduced if the estimated cost was within the standardised amount. Furthermore, this would determine a better version of any adopted construction method and materials used so that the amount of waste can be reduced. Based on the improved version of EVR index in conventional, semi-IBS construction methods, the finding has indicated between 0.026 and 0.126 based on six samples in Setia Alam from the year 2016 to 2021. Besides, the adoptions of additional assessment process like waste index, waste volume, waste generation rate, and waste level were also done in this research. This created a platform to assess the construction waste and preliminary cost from the perspective of developers. It created a complete assessment tool with a benchmark to assist developers in monitoring construction waste during field inspections. Based on the material waste justification and monitoring using tools and benchmark, future projects can be evaluated more effectively on sites and cost justification by contractors in the preliminary contract can halted from being overpriced. Furthermore, the benchmark between conventional, semi-IBS and IBS creates a progressive monitoring on on-sites waste generation. In addition, Google My Maps and Appsheet also create a cloud-based platform to monitor the amount of waste there.

ABSTRAK

Pertumbuhan pesat industri pembinaan Malaysia menyumbang secara tidak langsung kepada pertumbuhan ekonomi. Dengan peningkatan dalam teknologi bangunan baharu, pengeluaran sisa di pembinaan meningkat secara berkadar. Amalan pembinaan semasa memberi tumpuan kepada mekanisme kitar semula yang terhad di mana kebanyakan sisa bangunan dibuang di tapak pelupusan sampah. Ini disebabkan oleh kos awal yang lebih tinggi untuk pelupusan sisa yang mesti ditanggung oleh syarikat pembinaan. Kajian kes tentang pelaksanaan indeks Kos-Eko per Nisbah Nilai (EVR) dalam sisa pengurusan berdasarkan beberapa faktor yang mempengaruhi kesesuaian projek kediaman masih kurang. Oleh itu, matlamat kajian ini untuk meneroka lebih lanjut mengenai penggunaan EVR dalam menguruskan sisa pembinaan yang dihasilkan dari tapak. Pendekatan yang digunakan ialah pemantauan rapi menggunakan Peta Google, Lembaran Aplikasi dan lembaran hamparan. Kos pelupusan sisa pembinaan daripada penjanaannya pada peringkat awal boleh dikurangkan jika anggaran kos berada dalam lingkungan jumlah yang diseragamkan. Tambahan pula, ianya akan menentukan versi yang lebih baik daripada mana-mana kaedah pembinaan dan bahan yang digunakan supaya jumlah sisa dapat dikurangkan. Berdasarkan versi indeks EVR yang telah ditambah baik dalam konvensional, hasil dapatan bagi kaedah pembinaan separa IBS berdasarkan enam sampel di Setia Alam dari tahun 2016 hingga 2021 ialah antara 0.026 dan 0.126. Selain itu, penggunaan proses penilaian tambahan seperti indeks sisa, isipadu sisa, kadar penjanaan sisa, dan tahap sisa juga dilakukan dalam penyelidikan ini. Platform untuk menilai sisa pembinaan dan kos awal dari perspektif pemaju dapat diwujudkan. Ia juga sebagai alat penilaian lengkap dengan penanda aras untuk membantu pemaju dalam memantau sisa pembinaan semasa pemeriksaan lapangan. Berdasarkan justifikasi bahan sisa dan pemantauan menggunakan alat dan penanda aras, pada masa hadapan projek boleh dinilai dengan lebih berkesan di tapak dan justifikasi kos oleh kontraktor dalam kontrak awal boleh dihentikan jika terlalu mahal. Tambahan pula, penanda aras antara konvensional, separa IBS dan IBS mewujudkan pemantauan progresif ke atas penjanaan sisa di tapak. Selain itu, Peta Google dan Lembaran Aplikasi juga membolehkan platform berasaskan awan untuk memantau jumlah sisa di tapak.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BAT	-	Best Available Technologies
BIM	-	Building Information Modelling
BRC	-	British Reinforcement Company
BQ	-	Bill of Quantities
C&D	-	Construction and Demolition
EMS	-	Environmental Waste Management
EVR	-	Eco-costs per Value Ratio
GDP	-	Gross Domestic Product
GFA	-	Goss Floor Area
GI	-	Global Index
GIS	-	Geographical Information System
GPS	-	Global Positioning System
IBS	-	Industrialised Building System
LCA	-	Life Cycle Analysis
PPSPPA	-	Perbadanan Pengurusan Sisa Pepejal and Pembersihan Awam
PSS	-	Product Service System
SDG	-	Sustainable Development Goal
SWMP	-	Site Waste Management Plan
WBS	-	Work Breakdown Structure
WGR	-	Waste Generation Rate
WL	-	Wastage Level

LIST OF SYMBOLS

B	-	Width
C	-	Cost per trip
Ce	-	Cost of energy
Cep	-	Cost of eco-policy; taxes and levy
Ci	-	Cost of impact
C_{ph}	-	Cost per hour
Cr	-	Cost of rehabilitation
Cr1	-	Cost of all losses including health disorder and accidents
Cr2	-	Cost of damaged products as a result of harms
Crr	-	Cost of recycling and reuse
Crr1	-	Cost of implementation/operation
Crr2	-	Cost of conserving the recycling methods
Crr3	-	Cost of saving of reuse strategies
Cwc	-	Cost of waste control
Cwd	-	Cost of waste disposal
Cwd1	-	Cost of waste accumulation
Cwd2	-	Cost of waste transportation
Cwd3	-	Cost of waste landfill or incineration
Cwt	-	Cost of waste treatment
Cwt1	-	Cost of waste treatment system application
Cwt2	-	Cost of waste treatment system performance
Cwt3	-	Cost of waste treatment system maintenance
H	-	Height
L	-	Length
L_c	-	Labour cost
n	-	Energy consumption and production
N	-	Overall trip of disposal
P_c	-	Purchased cost
Tc_d	-	Total contract duration
Td_r	-	Total days required

T_d	-	Total duration
T_{ln}	-	Total labour needed
T_w	-	Total wastage
T_{wc}	-	Total wastage cost
$T_{w\%}$	-	Total wastage percentage
T_{wa}	-	Total waste volume every month
T_{wo}	-	Total work order
V	-	Waste bin volume
Vw	-	Volume of waste
W	-	Waste produced by project
W_i	-	Waste index
W_l	-	Wastage level

CHAPTER 1

INTRODUCTION

1.1 Introduction

Construction waste has been an issue with the utmost importance concerning the construction industry in the 21st century. It generates a high volume of construction waste worldwide and has constantly led to a negative effect on the environment (Abd Rahim and Kasim, 2017). Generally, all construction waste created by human activities leads to environmental concerns (Rahim et al., 2017). The construction industry is one of the major elements that have been associated with a strong impact on the earth. With the notable rise in world population growth, the importance of increasing buildings and other infrastructures has become a significant action in Malaysia as a developing country.

According to Rahim and Kasim (2017), Malaysian construction projects have been shown in the value of projected new construction works as reported by CIDB in the year of 2017 which was forecast at RM138.0 billion compare to RM 131.0 Billion in the year 2016. The construction industry's capability, high quality, and efficiency are important in attracting investors. As total, 6,305 construction projects involving RM166.4 billion were initiated in Malaysia in 2016. As a constantly developing country, Malaysia has been successfully implementing sustainable development as one of its national measures due to the crucial responsibility held by the construction industry in Malaysia in the generation of wealth for the nation and the social and economic buildings and infrastructures. The authorities, non-government organisations (NGO), and construction companies in Malaysia initiate the reduction of this environmental issue without restraining the need for development.

Solid Waste and Public Cleansing Management Corporation of Malaysia stated that eight million tonnes of construction waste are produced annually from

construction activity (Taha 2015). The past few decades of the construction industry have contributed to a continuous increase in construction waste due to fast development and urbanization (Saadi, Ismail and Alias, 2016). The severity of these environmental issues is increasing and should be controlled. Moreover, the increased building projects have led to a major waste generator and illegal disposal, which is rising in Malaysia. In a recent study by Rahim et al. (2017) states illegal dumping of construction waste was stated to be a distressing issue in Malaysia, which has negative effects on the economy, environment, and social. It was also highlighted that 933 tons of wastes accumulated in Klang Valley, including the dumpsites exceeded 52 numbers of sites as cited in (Saadi et al., 2016). This phenomenon caused harms to the environment, such as greenhouse gas emission. Previous researchers highlighted that the awareness among contractors regarding the construction waste management process in Malaysia was still lacking, while the illegal dumping generated from construction waste increased (Seow Ta Wee, 2016; Isnin, 2018). It was proven that an increase occurred in the projects leading to the construction waste (Ahmad, Husin and Zainol, 2014).

This research proposed an alternative to monitoring construction waste produced at the site by implementing an Eco-costing per Value Ratio (EVR) and determining the waste index between projects to control the produced waste and the total waste within the benchmark. It is an initiative to reduce disposal cost-based contract document and monitored towards sustainable development.

1.2 Background of the Problem

The background of the problem is the construction waste produced by the current construction method, which carries high operation cost in contract binding for site management. Van Ewijk and Stegemann (2016) stated that construction waste consists of three primary categories: material, time, and machinery wastes. These wastes are the most crucial elements with an important function in gaining sustainable development of the country that applies sustainable actions in the Malaysian

construction industry. This research emphasised materials waste, which could be as accurate as construction waste.

Sustainable development is an operation that mainly prioritises environmental issue. According to Yahya and Boussabaine (2006), one of the main themes of 'sustainable development' is waste management. Sustainable waste management is a medium contributing to reduced waste, reuse, recycle, and waste recovery. Waste is any losses from the activities that generate direct or indirect cost without adding any value to the product from the client's perspective. A contract bind document will be present in any construction works as a chain between client and contractor during the work progress.

As in contract bind, the construction waste should be disposed of by the contractor to the designated dumping ground. These criteria have been acknowledged with a contract amount under a preliminary contract. However, due to improper waste management, the construction waste channelled to the landfill is not adequate. As a result, the total construction waste management is stated in the contact instead of monitored, leading to high preliminary cost for this item in the tender document. The Star (2010) reported that landfill has led to social and environmental problems. The improper method of managing the waste leads to wastes filling the landfill.

According to Vasudevan (2015) rapid urbanisation leads to an increase in waste management cost and the emergence of landfill site problems in the nation. The majority of the landfills in Malaysia consist of poor management. The landfills function as dumping areas without a suitable standard system and proper treatment facilities for waste treatment. Besides, replacements for landfill sites are yet to be made (Vasudevan, 2015) This study determined the current construction waste disposal practices by localised contractors and identified the volume of construction waste produced based on the trade of work and stages throughout the contract period. By adopting Eco-costing per Value Ratio (EVR) in analysing the project healthiness, monitoring waste generation on monthly basis, and controlling and minimising the volume produced at the construction site.

1.3 Statement of the Problem

The process of minimising environmental impact has always been questioned. One of the methods to overcome this challenge by implementing an Eco-costing per Value Ratio (EVR) in construction waste management. However, a barrier is present in highlighting sustainable development in the construction industry due to the constructions waste, which is produced from the site in the total construction period that drastically increases annually. Furthermore, waste generation has become a crucial concern in Malaysia (Noor Yasmin Zainun, Ismail Abdul Rahman and Rosfazreen Azwana Rothman, 2016) with a high amount of construction waste created in the country due to the rapidly developing construction industry. The needs for houses and big infrastructure projects lead to the rise in construction waste (Ahmad et al., 2014). To ensure that this waste is generated to the correct channel for disposal, the higher preliminary cost in contract sum should be captured by construction companies. The approach of implementing EVR in construction is constantly monitored by tools and spreadsheet, while the production of construction waste is the initial stage that creates more possibilities to reduce the preliminary cost.

The latest breakthrough in construction waste management is the implementation of eco-costing as marginal prevention costs. Eco-costs are 'costs' associated with direct and indirect environmental impacts costs generated from the material purchased during construction (Masudi, 2013). Eco-costs are identified as costs of prevention measures, which require the reduction of the current emissions to a degree of sustainability. The author also stated that the costs are related to the measure and recycle product based on the Earth's approximate carrying capacity. Eco-costing is a model introduced by Vogtlander to achieve the double aims, sustainability, and economy (Vogtlander, Brezet and Hendriks, 2001), while Firman et al. (2012) introduced it, as an element of LCA studies using the economy-ecology approach, especially for consumer products.

In this research, the Eco-cost per Value Ratio (EVR) was adopted for construction waste management using the sustainability and economy-ecology approach, which focused on waste minimisation between conventional semi-IBS and

IBS construction towards sustainable development. In this case, the monthly waste production was monitored while the construction waste disposal cost was controlled This process involved the reduction of contract preliminary cost for sustainable waste management. Notably, the quantitative assessment was applied in this research to evaluate the environmental impact due to waste generation.

1.4 Research Objectives

This study aims to identify, analyse, improve, and monitor the construction waste produced from the site by implementing eco-costing for building material during the construction period to minimise construction waste and preliminary cost in contract documents.

The research objectives (RO) are as follows:

- To identify the cost associated with waste construction from different types of construction.

- To improve the EVR method in the current framework in line with the present construction process.

- To analyse the eco-cost per value ratio index resulting in waste construction from different type of construction.

- To develop an EVR monitoring method to monitor waste construction from different type of construction.

1.5 Research Questions

To fulfil the aforementioned research objectives, the following research questions (RQ) are presented.

Research Question 1: What is the cost associated with waste generation from different types of construction?

Research Question 2: Does the current EVR method useful for this research?

Research Question 3: What is the value of eco-cost per value ratio index for waste generation from the construction waste from different types of construction.

Research Question 4: What is the recommended monitor method for construction waste generation at the site?

1.6 Significance of the Research

This research creates an opportunity to control the construction waste disposal cost, which has constantly been an issue for any organisation through the implementation of eco-costs in construction practice. Subsequently, a platform could be created by the developers to implement eco-costing, which could be improved further to control construction waste. This method reduced the waste between conventional type, semi-IBS and IBS type in order the waste generation control and reduction from the preliminary stage of a project. The results were predicted to be the basis for more active progress to implement eco-cost in the construction industry to reduce the production of construction waste for sustainable development. Varies type of material adopted which related to sustainable development to reduce the construction waste. Industrialized Building System (IBS) and drywall was one of material which included in this assessment. This is to be in line with sustainable development goal (SDG). The reduction issues in the cost of construction waste disposal are one of the main issues in the construction industry. Moreover, the

implementation of efficacious eco-costing construction, waste disposal, and cost reduction will enhance sustainable development activities that provide environmental safety and economic benefits for the communities and consumers, including substantial savings in construction costs. This study was predicted to emphasis the significance of implementing eco-cost in the construction, efficient waste disposal and cost reduction for sustainable waste management for the sustenance of ecological system improved social welfare for all Malaysian citizens and future generations.

Industry validation required to justify the effectiveness of monitoring method based in research objective 4. Intended to ensure construction results in construction waste management that meets the operational needs of the user. In other words, checking that the finished product meets the requirements. Its helps to deep study and understanding of the system and process are made possible due to the validation. Its ease to investigate any deviation caused during the process. A validated method required less process control compare to manual and makes the monitoring process efficient. Construction waste that produced at site needs a proper platform to monitor and disposed. With the monitoring tools in place its ease the process of data collection and monitoring.

The method which adopted in this research based on documentation references on current construction waste management implemented by management. It is based on six active projects involving conventional, semi-IBS and IBS construction to justify the cost associated between material waste. Type of material used were identified as 10 sample. Analysis will be made through site inspection to collect data of material waste and volume. Justification of the EVR index is based on spreadsheet and monitoring using cloud based platform.

1.7 Scope and Limitation of the Research

The scope of the study was performed by reviewing the case studies to identify the effective method of construction waste management. The EVR index, was adopted and improved based on conventional, semi-IBS and IBS construction as per six project

sites. Subsequently, the focus could be placed on the purchase, delivery, and labour costs despite the lack of emphasis on these aspects in previous studies. Besides that, adoption of waste generation rate (WGR) and waste volume measured based varies type of construction material consist in this research. A case study on construction waste disposal cost and analysis of cost-saving in preliminary cost were identified from previous and current projects under the selected developer. Besides, the EVR index for sample selected sites was identified and evaluated in terms of the result based on the EVR benchmark for the Malaysian construction industry. This action assisted the study in controlling construction waste, which carried high preliminaries cost in the contract sum.

Cost justification on project value and monthly waste disposal cost for the selected construction method determined by documentation reference. The limitation of this study was from how the data collection of residential projects was considered, where the conventional and selected sustainable building material construction method within Setia Alam was employed. To illustrate, the sample selected project site by the developer who ventured into sustainable building material construction method in their ongoing projects. Therefore, this action would be a platform to justify the eco-costs in waste management, which would improve the disposal cost between conventional and sustainable building material construction methods.

The second limitation was the development in Setia Alam. This area was selected as a reference for the case study, which was divided into residential conventional and residential sustainable building material used construction method. The cost of construction waste disposal was evaluated from the residential project. Therefore, the implementation of eco-costing in the construction industry was justified at residential projects to control construction waste disposal cost in the contract preliminary.

The third limitation was based on EVR benchmarking for construction waste for conventional, semi-IBS and IBS construction development in Setia Alam. According to Masudi (2013), it focuses on identifying the benchmark value for waste index, wastage level, carbon footprint and eco-costs/value ratio (EVR). Whereby this

study was elaborated further on contribution of eco-costs/value ratio (EVR) as benchmarking for conventional, semi-IBS and IBS construction based on construction material such as concrete, rebar and BRC, bricks, timber formwork, drywall, plaster cement, tiles, ceiling, metal deck and IBS panel. It is was improvement from previous research on construction material. Besides that, identification of wastage level and waste index based on additional construction material and construction method has improved the index between projects for continues monitoring during construction period. Carbon footprint was not included in this study because this study focuses on implementing eco-costs for building material during the construction period to minimise construction waste and preliminary cost in contract documents. With the improved benchmarking, the construction waste production at site can be reduced and monitored.

1.8 Sustainable Construction Practice

By its very nature, the construction industry consumes a lot of natural resources. But there is more pressure on construction companies to minimise their environmental impact as a result of growing worries about climate change and the limited nature of these resources. The basic standards for a construction nowadays are changing due to changes in the construction standards. In terms of embedded energy consumption and building energy requirements, technological advancements are also opening up new opportunities. Adopting sustainable construction practices has significant obstacles, but it also has many advantages.

The goals of sustainable construction are to reduce the industry's impact on the environment. Sustainable construction methods include using renewable and recyclable materials, reducing the embodied energy in building materials, reducing the energy consumption of the finished building, reducing on-site waste, protecting the natural habitats during and after the construction phase.

1.9 The Organisation of the Thesis

The organisation of each chapter is presented in Figure 1 below:

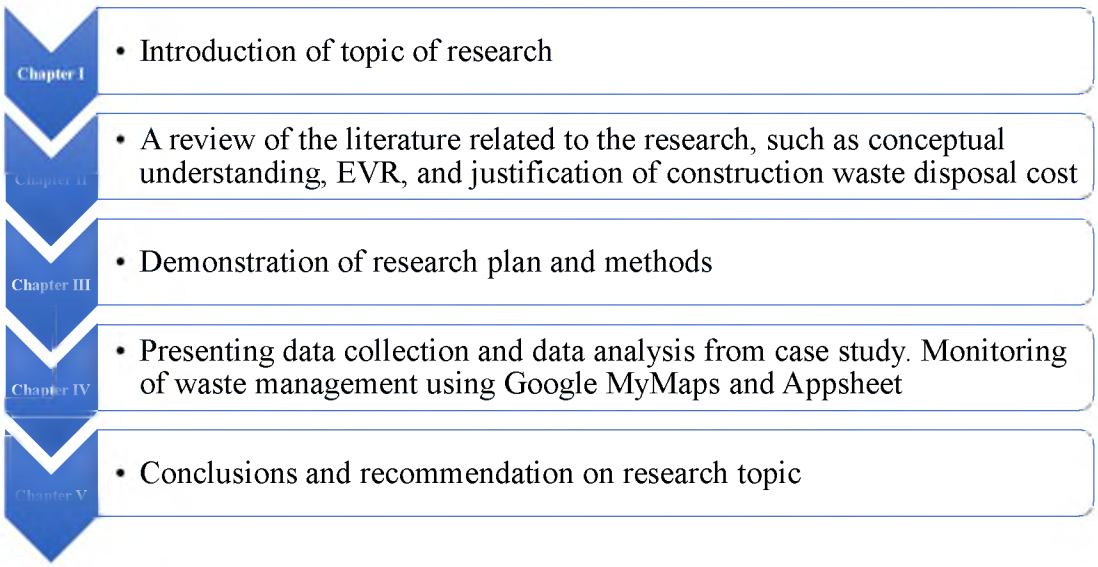

Figure 1.1 Organisation of the thesis

1.10 Summary

Sustainable waste management could significantly contribute to the national economy and reduce the use of natural resources by monitoring construction waste generation. This issue has been critical in the industry as the substantial construction of building and infrastructure is normalised and expected to increase in Malaysia. As mentioned in the statement of the problem for this research, construction waste management using sustainability and economy-ecology approach was made through the adoption of Eco-cost per Value Ratio (EVR) to minimise the construction waste by analysing the material usage and monitored throughout the project. This chapter presented the total flow of this research. To address the problem in the case study and identify the EVR index, it could be improved and implemented in construction practice between conventional and sustainable building material construction type for sustainable waste management.

REFERENCES

Abd Rahim, M. H. I., & Kasim, N. (2017). Conceptual model for systematic construction waste management. *MATEC Web of Conferences*, *87*, 1008.

Ahmad, A. C., Husin, N. I., Zainol, H., Tharim, A. H. A., Ismail, N. A., & Ab Wahid, A. M. (2014). The construction solid waste minimization practices among Malaysian contractors. *MATEC Web of Conferences*, *15*, 1037.

Ajayi, S. O., Oyedele, L. O., Akinade, O. O., Bilal, M., Alaka, H. A., & Owolabi, H. A. (2017). Optimising material procurement for construction waste minimization: An exploration of success factors. *Sustainable Materials and Technologies*, *11*, 38–46.

Akhtar, A., & Sarmah, A. K. (2018). Construction and demolition waste generation and properties of recycled aggregate concrete: A global perspective. *Journal of Cleaner Production*, *18Akadiri, P. O., Chinyio, E. A., & Olomolaiye, P. O. (2012). Design of a sustainable building: A conceptual framework for implementing sustainability in the building sector. Buildings, 2(2), 126-152.6*, 262–281.

Akinade, O. O., Oyedele, L. O., Munir, K., Bilal, M., Ajayi, S. O., Owolabi, H. A., Alaka, H. A., & Bello, S. A. (2016). Evaluation criteria for construction waste management tools: towards a holistic BIM framework. *International Journal of Sustainable Building Technology and Urban Development*, *7*(1), 3–21.

Antelava, A., Damilos, S., Hafeez, S., Manos, G., Al-Salem, S. M., Sharma, B. K., Kohli, K., & Constantinou, A. (2019). Plastic solid waste (PSW) in the context of life cycle assessment (LCA) and sustainable management. *Environmental Management*, *64*(2), 230–244.

Arumugam, S K, Muhamad, R., & Yahya, K. (2019). Implementation of eco-costs per value ratio (EVR) on construction waste management in Shah Alam, Malaysia. *IOP Conference Series: Materials Science and Engineering*, *513*(1), 12037.

Arumugam, Sharan Kumar, Muhamad, R., & Yahya, K. (2020). Mapping of construction waste for eco-costs per value ratio (EVR) index using Google My Maps in Shah Alam, Malaysia. *IOP Conference Series: Materials Science and Engineering*, *849*(1), 12046.

Begum, R. A., Satari, S. K., & Pereira, J. J. (2010). Waste generation and recycling: Comparison of conventional and industrialized building systems. *American Journal of Environmental Sciences*, *6*(4), 383.

Firman, M. A., Hassan, C. R. C., Sulaiman, N. M., Mahmud, N. Z., Mokhtar, S. N., & Khairulzan, Y. (2012). Eco-costs per value ratio assessment of construction waste: a study in Klang Valley, Malaysia. *Journal of Environmental Research and Development*, *7*(1), 99–106.

Ismam, J. N., & Ismail, Z. (2014). Sustainable construction waste management strategic implementation model. *WSEAS TRANSACTIONS on Environment and Development*, *10*, 48–59.

Isnin, Z., Ahmad, S. S., & Yahya, Z. (2018). Building Material Management Framework for Greener Adaptation Projects. *Asian Journal of Behavioural Studies*, *3*(9), 79–86.

Jalali, S. (2007). Quantification of construction waste amount.6th I*nternational Technical Conference of Waste*, Viseu, Portugal, October 2007.

Kanimoli, A., Adeleke, A. Q., & Taiwo, T. T. (2020). Organizational Structure Influence on Construction Waste Management Among Penang Malaysian Construction Industry: An Approach Via Partial Least Square Structural Equation Modeling. *Journal Homepage: Https://Www. Jobmer. Org*, *4*(1).

Kibert, N. C., & Kibert, C. J. (2008). Sustainable development and the US Green Building Movement-Profitable Development Projects can be good for the planet, too. *Prob. \& Prop.*, *22*, 21.

Kumaran, D. S., Ong, S. K., Tan, R. B. H., & Nee, A. Y. C. (2001). Environmental life cycle cost analysis of products. *Environmental Management and Health*.

Lau, H. H., Whyte, A., & Law, Pl. (2008). *Composition and characteristics of construction waste generated by residential housing project*.

Li, Y., Zhang, X., Ding, G., & Feng, Z. (2016). Developing a quantitative construction waste estimation model for building construction projects. *Resources, Conservation and Recycling*, *106*, 9–20.

Li, Z., Shen, G. Q., & Xue, X. (2014). Critical review of the research on the management of prefabricated construction. *Habitat International*, *43*, 240–249.

Lu, W., Chen, X., Ho, D. C. W., & Wang, H. (2016). Analysis of the construction waste management performance in Hong Kong: the public and private sectors compared using big data. *Journal of Cleaner Production*, *112*, 521–531.

Madureira, R. C., & Dias-Ferreira, C. (2019). Tag \& sensoring solutions overview for smart cities waste management. *Wastes: Solutions, Treatments and Opportunities III: Selected Papers from the 5th International Conference Wastes 2019, September 4-6, 2019, Lisbon, Portugal*, 402.

Mah, C. M., Fujiwara, T., & Ho, C. S. (2016). Construction and demolition waste generation rates for high-rise buildings in Malaysia. *Waste Management \& Research*, *34*(12), 1224–1230.

Malinauskaite, J., Jouhara, H., Czajczyńska, D., Stanchev, P., Katsou, E., Rostkowski, P., Thorne, R. J., Colon, J., Ponsá, S., Al-Mansour, F., & others. (2017). Municipal solid waste management and waste-to-energy in the context of a circular economy and energy recycling in Europe. *Energy*, *141*, 2013–2044.

Mandlik, P. P., Mohammad, G., Morey, S., Malik, S., & Khan, S. (2017). C \& D Waste Material Management in Construction Industry of Nagpur Region. *International Research Journal of Engineering and Technology*, *4*(3), 417–420.

Masudi, A. F. (2013). *Development of Construction Waste Indices in Malaysia*. Jabatan Kejuruteraan Kimia, Fakulti Kejuruteraan, Universiti Malaya.

Masudi, A. F., Che Hassan, C. R., Mahmood, N. Z., Mokhtar, S. N., & Sulaiman, N. M. (2011). Quantification methods for construction waste generation at construction sites: a review. *Advanced Materials Research*, *163*, 4564–4569.

Mestre, A., & Vogtlander, J. (2013). Eco-efficient value creation of cork products: an LCA-based method for design intervention. *Journal of Cleaner Production*, *57*, 101–114.

Nagapan, S., Rahman, I. A., Asmi, A., & Adnan, N. F. (2013). Study of site's construction waste in Batu Pahat, Johor. *Procedia Engineering*, *53*, 99–103.

Ng, L. S., Tan, L. W., & Seow, T. W. (2017, November). Current practices of construction waste reduction through 3R practice among contractors in malaysia: Case study in penang. In *IOP Conference Series: Materials Science and Engineering* (Vol. 271, No. 1, p. 012039). IOP Publishing.

Noh, N. M., & Mydin, M. A. O. (2018). Waste Minimization Strategy and Technique: Towards Sustainable Waste Management. *Analele Universitatii 'Eftimie Murgu*, *25*(1), 91-98.

Nugroho, A., Tongthong, T., & Shin, T. (2013). Measurement of the construction waste volume based on digital images. *Int J Civil Environ Eng IJCEEIJENS*, *13*(2), 35–41.

Osman, Wan Nadzri Bin, Zulkifli Mohamed Udin, and Dani Salleh. "Adoption level of sustainable construction practices: A study on Malaysia's construction stakeholders." *Journal of Southeast Asian Research* 2012 (2012): 1.

Papargyropoulou, E., Preece, C., Padfield, R., & Abdullah, A. A. (2011). Sustainable construction waste management in Malaysia: A contractor's perspective. *Management and Innovation for a Sustainable Built Environment MISBE 2011, Amsterdam, The Netherlands, June 20-23, 2011*.

Rahim, M., Kasim, N., Mohamed, I., Zainal, R., Sarpin, N., & Saikah, M. (2017). Construction waste generation in Malaysia construction industry: illegal dumping activities. *IOP Conference Series: Materials Science and Engineering*, *271*(1), 12040.

Saadi, N., Ismail, Z., & Alias, Z. (2016). A review of construction waste management and initiatives in malaysia. *Journal of Sustainability Science and Management*, *11*(2), 101–114.

Shen, L.-Y., Li Hao, J., Tam, V. W.-Y., & Yao, H. (2007). A checklist for assessing sustainability performance of construction projects. *Journal of Civil Engineering and Management*, *13*(4), 273–281.

Sheng, T. J., Islam, M. S., Misran, N., Baharuddin, M. H., Arshad, H., Islam, M. R., Chowdhury, M. E. H., Rmili, H., & Islam, M. T. (2020). An internet of things based smart waste management system using LoRa and tensorflow deep learning model. *IEEE Access*, *8*, 148793–148811.

Sjostrom, C., & Bakens, W. (1999). CIB Agenda 21 for sustainable construction: why, how and what. *Building Research \& Information*, *27*(6), 347–353.

Sodiq, A., Baloch, A. A. B., Khan, S. A., Sezer, N., Mahmoud, S., Jama, M., & Abdelaal, A. (2019). Towards modern sustainable cities: Review of sustainability principles and trends. *Journal of Cleaner Production*, *227*, 972–1001.

Solís-Guzmán, J., Marrero, M., Montes-Delgado, M. V., & Ramírez-de-Arellano, A. (2009). A Spanish model for quantification and management of construction waste. *Waste Management*, *29*(9), 2542-2548.

Soust-Verdaguer, B., Llatas, C., & Garc\'\ia-Mart\'\inez, A. (2017). Critical review of bim-based LCA method to buildings. *Energy and Buildings*, *136*, 110–120.

Starovoytova, D. (2018). Solid Waste Management (SWM) at a University Campus (Part 1/10): Comprehensive-review on legal framework and background to waste management, at a global context. *Journal of Environment and Earth Science*,

8(4), 948–2225.

Subramaniam, S., Nagapan, S., Kupusamy, K., Manian, H., Daud, Z., & others. (2018). Investigate How Construction Waste Generation Rate is Different for Every Types of Project in Peninsular Malaysia using Site Visit Method. *International Journal of Integrated Engineering*, *10*(1).

Taha, M. P. (2015). What a waste: solid waste management and the Malaysian perspective on construction waste generation and management. *Kuala Lumpur: Solid Waste and Public Cleansing Management Corporation*, 14–18.

Umar, U. A., Shafiq, N., Malakahmad, A., Nuruddin, M. F., & Khamidi, M. F. (2017). A review on adoption of novel techniques in construction waste management and policy. *Journal of Material Cycles and Waste Management*, *19*(4), 1361–1373.

Van Ewijk, S., & Stegemann, J. A. (2016). Limitations of the waste hierarchy for achieving absolute reductions in material throughput. *Journal of Cleaner Production*, *132*, 122–128.

Vasudevan, G. (2015). Study on the demolition waste management in Malaysia construction industry. *International Journal of Scientific Engineering and Technology*, *4*(3), 131–135.

Vogtländer, J. G., Brezet, H. C., & Hendriks, C. F. (2001). The virtual eco-costs '99 A single LCA-based indicator for sustainability and the eco-costs-value ratio (EVR) model for economic allocation. *The International Journal of Life Cycle Assessment*, *6*(3), 157–166.

Wong, J., Wang, X., Li, H., & Chan, G. (2014). A review of cloud-based BIM technology in the construction sector. *Journal of Information Technology in Construction*, *19*, 281–291.

Wortmann, A. E. (2014). *Critical Factors in Effective Construction Waste Minimisation at the Design Stage: A Gauteng Region Case Study*. University of the Witwatersrand, Faculty of Engineering and the Built~….

Yahya, K., & Boussabaine, A. H. (2006). Eco-costing of construction waste. *Management of Environmental Quality: An International Journal*.

Yuan, H., Lu, W., & Hao, J. J. (2013). The evolution of construction waste sorting on-site. *Renewable and Sustainable Energy Reviews*, *20*, 483–490.

Zainordin, N., & Mei, C. T. Y. (2015). An Insight of Sustainable Development-A Study Among Construction Professional in Malaysia. *International Journal of Scientific \& Engineering Research*, *6*(1).

Zainul Abidin, N. (2009). Sustainable Construction In Malaysia Developers' Awareness.

Zainun, N. Y., Rahman, I. A., & Rothman, R. A. (2016). Mapping of construction waste illegal dumping using geographical information system (gis). *IOP Conference Series: Materials Science and Engineering*, *160*(1), 12049.

LIST OF PUBLICATIONS

Indexed Conference Proceedings

1. **Arumugam, S. K.,** Muhamad, R., & Yahya, K. (2019, April). Implementation of eco-costs per value ratio (EVR) on construction waste management in Shah Alam, Malaysia. In *IOP Conference Series: Materials Science and Engineering* (Vol. 513, No. 1, p. 012037). IOP Publishing. **(Indexed by SCOPUS)**

2. **Arumugam, S. K.,** Muhamad, R., & Yahya, K. (2020, May). Mapping of construction waste for eco-costs per value ratio (EVR) index using Google My Maps in Shah Alam, Malaysia. In *IOP Conference Series: Materials Science and Engineering* (Vol. 849, No. 1, p. 012046). IOP Publishing. **(Indexed by WoS)**

Non-Indexed Conference Proceedings

1. **Arumugam, S. K.,** bt Muhamad, R., & Yahya, K. (2017, October). A REVIEW OF ECO-COSTS PER VALUE RATIO IN MALAYSIAN CONSTRUCTION INDUSTRY TOWARDS SUSTAINABLE DEVELOPMENT. In *e-PROCEEDINGS* (p. 1).

2. **Arumugam, S. K.,** Muhamad, R., & Yahya, K. (2019). Implementation of Eco-Costs per Value Ratio (EVR) in Construction Industry to reduce Construction Waste Disposal cost in Shah Alam, Malaysia towards Sustainable Development. *Journal of Advanced Research in Business and Management Studies*, *16*(1), 24-27.