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BARRIERS IN IMPLEMENTING SUSTAINABLE PILING CONSTRUCTION PRACTICES IN SRI LANKA

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ABSTRACT

The construction of pile foundation is a multifaceted activity among rest of the construction activities that are performed by heavy machines, materials, and energy sources generating substantial amount of CO_2 and greenhouse gases along with many other forms of environmental pollution. Sustainable piling construction guarantees that the whole piling process meets environmental sustainability and ultimately human health and wellbeing. Many countries around the world, including United States, China, the United Arab Emirates, are in the forefront of reengineering piling construction activities. Implementation of sustainable practices in piling construction Sri Lanka is still at a low level. Succinctly, several hindrances and barriers can be identified when adopting sustainable piling construction practices. Hence, the aim of this paper is to identify the environmental impact due to the current piling construction practices in Sri Lanka and to investigate barriers in implementing sustainable piling construction practices. A questionnaire survey was conducted among thirty (30) experts in piling construction. Significant barriers were identified using the relative importance index technique in data analysis. The findings revealed that among the ten (10) barriers identified, cost overrun and poor pile design, investment risk, lack of awareness of sustainable techniques and technologies as the top three (3) barriers in implementing sustainable piling construction practices. The study clearly identified the need for improving sustainability practices that can also enhance cost-effectiveness and performance efficiency. Findings of this study will be useful in formulating strategies to overcome the barriers and improve sustainability practices in the local construction industry.

Keywords: *Barriers; Environment impact; Piling construction; Sustainable practices.*

1. INTRODUCTION

Construction industry worldwide is a significant cause for degradation of the environment and contribute to pollution and global warming. In the recent era, climate change has become a critical challenge to the entire biosphere, primarily caused by greenhouse gases (GHGs). The phenomenon of GHGs is the retention of heat by Carbon Dioxide (CO_2) and other greenhouse gases within the atmosphere (Hannigan *et al.*, 2016) causing an

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increase in average temperature, subsequently global warming and climate change (King and Harrington 2018). According to the analysis of Seo *et al*. (2016), 40% of the resources that contribute to the world economy are consumed by the construction industry, which is responsible for the generation of around 40% to 50% of the GHGs. Most of the construction activities do directly rely on machineries which accounts for 50% of all CO_2 emissions produced by the construction industry due to their excessive volume of energy consumption (Jassim *et al.,* 2017).

Chen *et al*. (2019) have emphasised that the contribution of CO_2 and other greenhouse gasses (GHGs) in the construction sector is significant since a huge proportion of machinery is utilized in piling construction. Ghoraba *et al*. (2016) have stated that piling is one of the most complex construction tasks and several uncertainties can be encountered during the execution which led to cost overrun, materials wastages, and delay in project completion. Bored pile construction is identified as the most common practice of piling method (Taghavi *et al.,* 2015). Sandanayake *et al.* (2014) mentioned that bored pile construction is employed by heavy machines, materials and energy that generate a high emission rate of CO_2 and waste generation.

Sustainable construction encompasses three prime pillars viz. economic, environmental, and social performance of the industry (Li *et al.,* 2018). In terms of piling construction, sustainable practices focus on material usage, energy consumption, wastage generation, noise and vibration, and impact to the ground (Ametepey *et al.,* 2015). As cited by Basu *et al*., (2014), cost-effectiveness and sustainability can be achieved by implementing sustainable practices in piling construction through adequate soil investigation, economic design, and efficient usage of machinery, materials, and resources. Even though "environmental sustainability" and "going green" have been major concepts in the construction industry for a long time, statistics make evident that the side-effects of construction activities are contributing to some negative impact on every nation (Ojo *et al.,* 2015). Consequently, re-engineering the entire construction process, including piling activities has become significant to decrease the environmental impacts.

Sri Lanka is significantly slow in accepting sustainable piling construction practices, where many barriers can be identified during the implementation process. The majority of the construction contractors are not capable of overcoming these barriers. Thus, these barriers need to be studied well before implementation. Although many past studies have been conducted on the environmental impact of the construction industry in general, none of studies have attempted to identify the impact on the environment due to current practices with piling construction in Sri Lanka. Therefore, aim of this paper is to identify the environmental impact of the current piling construction practices and investigate barriers in implementing sustainable piling construction practices in Sri Lanka.

2. LITERATURE SYNTHESIS

2.1 PILING TYPES AND CONSTRUCTION PRACTICES

Pile is the columnar component in a foundation that transfers load from the superstructure to weak soil at shallow depth, compressible strata or water, or less compressible soils, or rock (Babu *et al.,* 2020). Building foundations, machinery foundations, and bridge piers and abutments, embedded retaining walls are supported by piles to carry out vertical and horizontal loads (Xu *et al.,* 2015). Mucciacciaro and Sica (2018) have declared that displacement piles where the material of the pile, or a former into which the pile is to be placed, is forced into the ground, by displacing the ground. The analysis of Misra and Basu (2011) have indicated that from the environmental impact point of view, the driven piles perform better in the sandy profile but, for the clayey profile, the performance depends on the design load. Additionally, it has been revealed that a geographical investigation is executed to find out the rock mass or soil properties of where the structure is supposed to be laid. Common methods used for proceeding in the process of boreholes are percussion boring, shell and auger, wash boring, auger boring, and rotary drilling in replacement piles (Hannigan *et al.,* 2016). Moreover, the excess consumption of concrete is due to some causative factors that can be identified in piling construction. Over break arises due to the local collapses of the pile bore walls resulting in cavities and cause to the wastage of concrete (Jami *et al.,* 2019). Mantha and de Soto (2019) have mentioned that the quality and level of the boring support fluids are required to be kept under tight control during pile bore drilling to avoid such bore wall collapses. Besides, it is revealed that the efficiency in the drilling operation will reduce the risk of borehole collapse, resulting in a reduction in excess concrete consumption. Similarly, if the temporary casing is extracted too rapidly with an insufficient head of concrete, defects may occur in the pile construction due to soil contamination of the concrete (Wang and Wang 2020). Proper coordination in the rate of concrete injection and the rate of extraction of the auger in piles is necessary to avoid necking in the piles. Hole cleaning essentiality needs to be carried out as immediately as possible after the boring has finished, otherwise, the mud penetrated from the boring will subside and creates difficulties in cleaning the hole, or else the hole can be collapsed as well (Gan *et al.,* 2015). Whereas in replacement piles, the ground is removed by augering, drilling, etc., and the soil is replaced with cast-in-situ concrete. All these major activities in the piling process are supported by sub-activities that involve various techniques, plants, and equipment.

2.2 ENVIRONMENTAL IMPACT DUE TO CURRENT PILING CONSTRUCTION PRACTICES

According to Misra and Basu (2011), the impact on the environment connected with piling construction can be commonly recognised in terms of emissions of CO_2 which are based on volume and energy consumption, waste generation and soil contamination, noise, and vibration, water, and air pollution. The main materials in piling construction are concrete and steel. CO_2 and GHGs are produced by the manufacturing, utilizing, and transporting of concrete and steel (Miller 2018). Approximately 460kg of CO_2 is generated per ton of reinforcement steel and a cubic meter of in-situ concrete produces 1770kg of CO_2 emissions (Miller *et al.,* 2016). Moreover, fossil fuel used in heavy machinery in pile construction is also known as a significant contributor to CO_2 emission as it produces 2.62kg of CO_2 emission from 1 litre of diesel, and 0.537 kg of CO_2 emission per 1 kWh of electricity usage (Masih-Tehrani *et al.,* 2020). Saravanan (2011) has revealed that even though epoxy coated steel is used for piling construction in the UAE as corrosion protection to the reinforcement, the coating factories consume a lot of energy for this process, resulting in GHG emissions. Poor control of such kinds of activities leads to increase in global warming and climate changes which are the key issues of sustainability. Howell (2015) has revealed that contamination arising from the effects of aggressive ground conditions on materials used in piles, creation of preferential flow paths, driving contaminated materials during installation and process of concreting or grouting allow surface water infiltration into contamination causing the risks of subsequent exposure to site workers and residents. Wu *et al*. (2020) and Zha *et al*. (2018)

have emphasised that potable water is used for concrete manufacturing and pile drilling activities and it is being produced in most countries by desalination process of seawater or natural water resource. For this process, huge amount of fossil fuel is burned which in turn creates CO_2 emission in the atmosphere. Noise is created by large diameter piles during sealing into the ground by using a Kelly bar of the drilling rig or hammer (Mangushev 2016). Moreover, it may lead to vibrations for temporary casing installation using a vibrator. As per Xu *et al*. (2015), the real drilling technique is free of vibrations; the engine operation and Kelly bar operation in the drilling rig results in the drilling process making some noise. According to the geophysical investigation of the building foundation of Mohsenian *et al*. (2019), ground-borne vibrations that occur from piling construction lead to energetic strains within adjacent buildings. Such kinds of vibrations may be significant enough to affect the structure but the more frequent concern is occupants' disruption (Babu *et al.,* 2020). Piling construction is predominantly powered by the successful utilization of materials, natural resources and heavy plants (Mohajerani *et al.,* 2016). As a result, the scarcity of natural resources has become a threat to sustainable construction.

2.3 SUSTAINABLE PILING PRACTICES

The application of sustainable development practices to the construction industry reflects as sustainable construction (Shan *et al.,* 2017). As per Gaikwad and Shelavale (2017), construction and design approaches which encourage the fulfilment of goals allied with the triple bottom lines, which are "economic sustainability" for inspiring economic growth, "environmental sustainability" for minimizing environmental impacts, and "social sustainability" for social wellbeing are known as sustainable construction practices. It donates tremendous utility to create economic, environmental, and social development and ultimately the sustainable built environment (Ojo *et al.,* 2015). The use of viable practices in piling construction may achieve cost-effectiveness and sustainability. The enhancement of construction quality, efficiency, and safety are of utmost critical aspects of sustainable piling construction. Further, Saravanan (2011) has revealed that sustainable practices in piling construction played a major role to attain competitive advantage through cost-effectiveness, performance efficiency, and sustainability during the 2008 construction industry recession in the United Arab Emirates (UAE). The key areas to be focused in improving the sustainable piling process are as follows.

Reduction of CO_2 emission is mainly associated with minimizing fuel and materials consumption and reducing waste generation in piling construction, which can be achieved through quality improvement of construction processes by implementing sustainable construction practices (Ametepey *et al.,* 2015). Noise and pollution are associated with the selection of the method of piling construction; suitable methods, and alternative ground stabilisation technologies can be used according to the viability to avoid environmental impacts (Jassim *et al.,* 2017). An adequate geotechnical investigation should be carried out before pile foundations are designed and the method of construction determined. It is essential to carry out a site exploration to ascertain the character and variability of the strata underlying the site of the proposed structure. As per Jami *et al*. (2019), the concept of reuse and recycling describes the idea that all components and materials can ever be reused, refurbished, and recycled, support life, and never have to be deposited as waste. Ground improvement techniques can be adapted for an increased range of ground conditions and environmental constraints. In-situ ground improvement using the high energy compaction and monitoring technologies comprises the improvement of the engineering properties of in-place ground materials at depth, both above and below the groundwater level (Saravanan 2011). The main advantage of this system is emphasized by Scott *et al*. (2019) as; quicker completion, no excavation is needed and there are no impacts on the environment, and this process involves very lesser equipment requirements in comparison to pile foundations. Likewise, sustainable piling construction technologies and techniques ensure that designed and constructed structures comply with high environmental standards and minimise the utilisation of resources, reducing waste, promoting the environment, and preserving human health and wellbeing (Yin *et al.,* 2018).

2.4 BARRIERS IN IMPLEMENTING SUSTAINABLE PILING CONSTRUCTION METHODS: GLOBAL ASPECTS

Lack of awareness on the relationship between environmental impacts and sustainable benefits becomes the major barrier for sustainable constructions (Gan *et al.,* 2015). According to Xu and Shi (2018), poor design and supervision of engineers have become a barrier to minimise material usage and related carbon footprint reduction. " Lack of piling construction expertise" has been highlighted as a key concern by Gianella and Studlein (2017). Moreover, lack of knowledge of ground improvement technologies and efficient pile construction techniques of the Engineer will hinder sustainability and cost-effectiveness in piling construction. Misra and Basu (2011) have mentioned that purchasing reusable anchors, and fuel efficiency devices will help contractors to reduce operational cost, however, the initial cost is required for the procurement and installation of such items in the process. Furthermore, contractor thinking only from the financial perspective also hinders the implementation of energy-saving measures which in the long run may make a substantial saving in cost and environmental friendliness. Hence, the risk attached to implementing a new method is crucially high in the construction industry, it can either be positive or negative and results in a reluctance to the contractor's attitude to introduce sustainable construction practices (Shan *et al.,* 2017). Unavailability of sustainable materials at the same time as the availability of unsustainable materials acts as a barrier to the use of sustainable materials in construction. Even though the relatively low cost of electricity and low energy prices are main causes of high electricity consumption in the Gulf Cooperation Council (GCC) countries (Taghavi *et al.,* 2015), high energy cost including electricity, fuel, oil, and gas affected cost-effectiveness and ultimately sustainability in Asian counties (Mangushev 2016). Hence, the electricity demand in GCC countries is exceeded and it resulted in increment in CO_2 emission. Hannigan *et al*. (2016) have mentioned that sustainable regulations and policies are to encourage sustainability practice in the construction industry, by awarding incentives and rewards to the organisations that practice sustainability. The lack of having such kind of rules and regulations reflects as a major barrier.

Zhussupbekov and Omarov (2016) have highlighted that the lack of skill level is also a barrier to sustainability, as sustainable construction needs skilled workers for the minimization of material wastages and maximizing process efficiency for added value by minimization of resource depletion, minimization of environmental degradation and creating a healthy built environment. Lack of coordination to manage resources more efficiently in piling construction is also a barrier for sustainable construction.

3. METHODOLOGY

The study focuses on identifying the impact on the environment due to current practices with piling construction and investigates barriers in implementing sustainable piling construction methods to minimise environmental issues in Sri Lanka. Thus, a quantitative research approach was adopted since it involves collecting and converting data into a numerical form (Jabbar 2017) so that statistical calculations can be made (Quick and Hall 2015) and conclusions are drawn, generalizing it across groups of people (Kas *et al.*, 2019). Besides, the literature was used as a secondary source to identify the impact on the environment and global barriers in implementing sustainable piling construction, and subsequently, all these factors were questioned in a questionnaire survey which was conducted to investigate the significant barriers to implementing the sustainable piling construction method to minimize environmental issues in Sri Lankan construction industry. According to Ikart (2019), a questionnaire survey helps to gather information from people about a predefined research problem and collects data during a short period from a large number of respondents scattered over a wide geographical area. The questionnaire can be divided into sections following the research objectives and included with both open-ended questions to encourage the respondent to provide free responses and closed-ended questions to get straightforward responses with quick answers (Antwi and Kasim 2015). The questionnaire survey was conducted among industry practitioners selected using the purposive sampling method to ensure that all the respondents had the relevant knowledge, authority, and experience in piling construction. Accordingly, 45 questionnaires were distributed among the survey participants and 30 questionnaires were eligible to consider for the detailed analysis which was received within the stipulated survey time frame. Besides, the number of respondents was limited due to time constraints, the accessibility issues with piling experts, and travel restrictions in Sri Lanka. The composition of the respondents is illustrated in Table 1.

Table 1: Details of respondents

		Percentage
Type of Organization	Piling construction firms	53%
	Civil construction firms	44%
	Consultancy firms	3%
Designation of Respondents	Project manager	24%
	Engineer	33%
	Quantity surveyor	40%
	Other	3%
Work Experience (Years)	less than 5	33%
	5 to 10	54%
	10 to 15	10%
	More than 15	3%
Experience in Green Construction Projects	Yes	33%
	No	67%

Quantitative data that is gathered from the questionnaire survey were analysed using the relative importance index (RII). RII is a well-recognized statistical tool used to measure the relative significance of several attributes and rank them (Wilfred and Sharafudeen 2015). The barriers to implementing the sustainable piling construction method that significantly affects the Sri Lankan construction industry were identified based on their RIIs that were calculated using Equation 01. According to Khaleel and Nassar (2018), the effect of each barrier group with RII values as Very High (RII > 0.8), High (RII 0.8-0.6), Average (RII – 0.6- 0.4) and Less (RII < 0.4).

$$RII = \frac{\Sigma (Wn)}{A \times N} \qquad (01)$$

Where, W- rating of each factor given by the respondent, n - frequency of the responses, N - total number of responses, A - highest weight.

4. RESEARCH FINDINGS AND DISCUSSION

The significance of the study is ascertained through the critical comparison of literature findings and analytical research findings. The key findings of the study are discussed in the following sub-sections.

4.1 AWARENESS OF SUSTAINABILITY ISSUES IN THE PILING CONSTRUCTION

The environmental impacts identified through the literature review were questioned under the following major impact categories during the survey.

1. Water, air, and sound pollution
2. Carbon emission and depletion of the ozone layer
3. Climate change and global warming
4. Scarcity of natural resources

Initially, the level of awareness was investigated to gather the present state of knowledge among the professionals engaged in piling construction. Figure 1 depicts the general awareness of the respondents concerning the sustainability issues in piling construction. The level of awareness is identified in terms of strong, moderate, weak and unawareness.

As shown in Figure 1, 30 % to 46% of respondents had strong awareness that due to piling construction there is an impact to above factors as denoted in blue. None had total unawareness.

Mohsenian *et al.* (2019) have emphasised the point revealed by Mangushev (2016) that climate change and global warming is an indirect result of piling construction and the awareness of it is at a low level. Yin *et al*. (2018) have mentioned that very few contractors and private developers are aware and spend efforts in considering the environment and developing the concept of recycling building materials. Shan *et al*. (2017) have concluded that the level of knowledge and awareness of project participants, especially project managers, with regards to environmental impacts of piling construction processes needs to be enhanced. Gaikwad and Shelavale (2017) have agreed with Zhussupbekov and Omarov (2016) by pointing that enhancing the awareness of the major environmental impacts of piling construction processes will help to improve the effectiveness of environmental management systems.

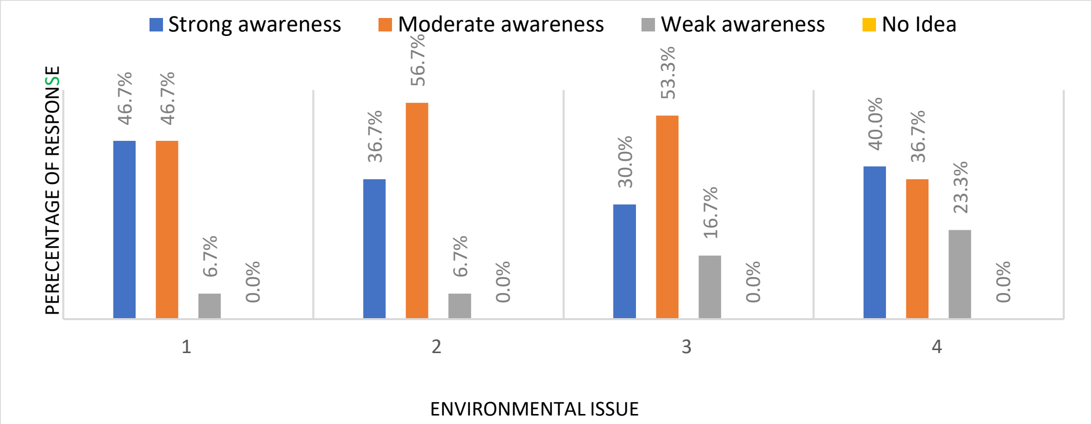

Figure 1: Awareness of the respondents on environmental impact due to piling construction

Further, the results indicate majority of the respondents have some kind of awareness about the environmental impact due to piling construction in Sri Lanka and moreover, the study revealed that majority of firms and institutions do not have proper environmental impact assessment practices.

4.2 BARRIERS IN IMPLEMENTING SUSTAINABLE PILING CONSTRUCTION IN SRI LANKAN CONSTRUCTION INDUSTRY

Based on the secondary data, ten barriers were identified, and respondents were asked to rank the relevancy of each barrier considering the Sri Lankan construction industry using the Likert scale 1 to 5 and the results are presented in Table 2.

Table 2: Barriers in implementing sustainable piling construction in the Sri Lankan construction industry

Description	SA	A	MA	D	SD	RII	Rank	Effect
Poor skill level and knowledge of labourers	5	8	10	3	4	0.647	6	High
Poor coordination among parties and site condition	4	9	11	5	1	0.667	4	High
Cost overrun due to poor pile design	4	17	7	1	1	0.747	1	High
Lack of awareness on sustainable pile construction techniques and technologies	6	10	7	5	2	0.687	3	High
Rules and regulations	3	5	9	10	3	0.567	8	Avg.
Investment risk	4	13	10	3	0	0.720	2	High
Lack of piling construction expertise	4	8	10	6	2	0.640	7	High
High cost of energy including electricity, fuel, oil, gas, etc.	3	10	12	4	1	0.667	4	High
Unavailability of sustainable materials	1	6	10	11	2	0.553	10	Avg.
Lack of awareness on environmental impacts and sustainable benefits	3	2	14	8	3	0.560	9	Avg.

SA: Strongly Agree-5; A: Agree-4; MA: Moderately Agree-3; D: Disagree-2; SD: Strongly Disagree-1

As depicted in Table 2, seven barriers were identified as significant barriers since RII values were between 0.6 and 0.8 in scale. According to the respondents, cost overrun due to poor pile design has been revealed as the major barrier to implementing sustainable piling construction practices in Sri Lanka. During the construction planning and design stage, sustainability assessment can be incorporated to ensure the overall sustainability and the cost-effectiveness of the project. The analysis of Meena and Luhar (2019) has indicated that in the utilisation of resources, driven piles use resources more efficiently than drilled shafts and ultimately avoid the cost overrun. Efficient and reliable pile design leads to saving of resources usage and the cost in piling construction and increases the profit (Saravanan 2011). Moreover, the design phase is fundamentally important in sustainable construction because it is responsible for defining the sources and the constructive technology that will be implemented by avoiding nonvalue added activities on site. The investment risk is recognised as the second most impacted barrier, which takes RII values as 0.720. The risk attached to implementing sustainable practices in piling construction is higher (Monahan and Powell 2011) and it leads to the contractor's reticence to implement sustainable construction (Li *et al.,* 2018).

Lack of awareness on sustainable pile construction techniques and technologies was highlighted through literature review and it is positioned as the 3rd barrier to sustainable piling construction in Sri Lanka. In-situ ground improvement is a modern technique of piling construction which has several advantages such as high speed of construction, less excavation, less equipment needed, cost effectiveness and environmental friendliness (Scott *et al*., 2019). Sondermann *et al.* (2016) have discussed Vibro stone columns (VSC) and they revealed that it is an economical and environmentally sustainable alternative to piling foundation solutions. Rapid impact compaction is a technique utilizing a 7-ton hydraulic piling hammer that repeatedly hits the ground with a heavy 1 to 1.5m diameter steel foot (Gianella and Stuedlein 2017). As per the respondents, such kind of piling construction techniques and technologies are not implemented in Sri Lanka due to a lack of knowledge.

Subsequently, "Poor coordination and condition of the site", "High cost of energy including electricity, fuel, oil, gas, etc." have been identified as the next important barriers to implement sustainable piling construction and RII value was0.667. Site pre-investigation, sub-surface obstacles, soil type, maintainability of pile equipment, lack of experience, disposal system of excavated soil, and site restrictions are the summarised basic factors affecting the productivity of the installation process of piling (Taghavi *et al.,* 2015). Construction waste disposal on-site is a critical issue and it results in environmental concerns such as degradation, habitant destruction, soil and groundwater contamination, and even generation of methane (Shan *et al.*, 2017). Even though the high cost of electricity and high energy prices has significantly impacted in Sri Lanka, Qader (2009) has argued that organizations in UAE ignored the opportunity for energy conservation and related triple bottom line benefits which can be achieved by adopting sustainable practices, due to the cheaper energy cost and sufficient availability of fossil fuel.

Poor skill level and knowledge of labourers and lack of piling construction expertise were identified as next significant barriers where RII was 0.647 and 0.640 respectively. It was similarly confirmed by Zhussupbekov and Omarov (2016) who identified that the poor skill level of labourers significantly influences the waste generation, quality of works, completion schedule, and the overall cost. Involvement of the most appropriate piling construction expertise with the required skill level and experience to deliver the sustainable project provide also the best value for money to the client (Monahan and Powell 2011). Rules and regulations, which motivate sustainable piling construction practices; lack of awareness on environmental impacts; and sustainable benefits, and unavailability of sustainable materials were identified as average effect barriers related to the Sri Lankan context since RII values of those three factors were less than 0.6. Jami *et al*. (2019) emphasised that rules and regulations, which motivate sustainable piling construction and unavailability of sustainable materials are barriers in Asian countries than the lack of awareness on environmental impacts and sustainable benefits, as it is confirmed by the survey results from the respondents. Hannigan *et al*. (2016) have emphasised that government plays an imperative role in accomplishing sustainability through the development and enforcement of the rules and regulations, which must be accepted by the industries. Even though, unavailability of sustainable materials is identified as a barrier to implement sustainable piling construction through secondary data, out of thirty (30) respondents eleven (11) respondents disagreed in the survey and placed it in 10^{th} rank in the Sri Lankan context.

5. CONCLUSIONS

The literature synthesis of this paper focused on piling construction, its impact to the environment and investigated barriers to implementing sustainable piling construction methods. The study revealed that there is an impact on water, air, and sound pollution; CO_2 and GHGs emission and depletion of the ozone layer; climate change and global warming, and scarcity of natural resources due to current practices of piling construction which ultimately effect on the environment. The findings also revealed that still less attention is given for the impact assessment of the eco system.

The literature synthesis also highlighted different technologies in piling construction and the underlying environmental concerns. Alternative technologies and improvement measures also have been identified. A range of barriers that lead to lack of sustainable practices in piling construction was identified from the literature synthesis and summarized in to ten (10) key factors.

In the global perspective, lack of awareness on the relationship between environmental impacts and sustainable benefits has become the major barrier for sustainable constructions. High energy cost including electricity, fuel, oil, and gas affected cost-effectiveness and ultimately sustainability. Sustainable practices in piling construction play a major role to attain competitive advantage through cost-effectiveness, performance efficiency, and sustainability. Contractor thinking only from the financial perspective hinders the implementation of energy-saving measures which in the long run may make a substantial saving in cost and environmental friendliness. Need of skilled workers for the minimization of material wastages and maximizing process efficiency for added value that minimise resource depletion, environmental degradation for creating a healthy built environment is also a key barrier.

The detailed questionnaire survey investigated the barriers that hinder sustainable piling practices in the Sri Lankan construction industry using the Relative Index Ranking. Findings showed that cost overrun due to poor pile design, investment risk, and lack of awareness on sustainable pile construction techniques and technologies as the most significant barriers to implement sustainable piling construction practices in Sri Lanka.

There is a need for promoting awareness among the professionals engaged in piling and construction on sustainable piling practices while also improving the skills of the workforce. The findings of this study will be useful in formulating strategies to overcome the barriers in sustainable piling practices and introducing new piling technologies in the Sri Lankan construction industry.

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