The Existing Sustainable Features in the Sri Lankan Road Construction

MGK Hasanthika[1#], V Disaratna[1] and HC Victar[1]

[1]*Department of Building Economics, University of Moratuwa, Sri Lanka*

[#] hasithchathuranga122@gmail.com

***Abstract**: One of the world's greatest natural resource exploiters relies on the building and materials sectors for physical and biological support. The concept of sustainable development has been around for more than 30 years, and it connects development and the environment. The road industry emits the most greenhouse gases, both directly and indirectly, due to the usage of fossil energy in mining, transporting, and paving operations. As a result, road development contributes significantly to pollution in Sri Lanka's environment. However, the success of environment-friendly road construction is not at a sufficient level in Sri Lanka mainly a low level of attention given to sustainable development. Hence, this research focused on enhancing road construction success through a better understanding of sustainable development.*

An extensive literature synthesis was carried out to review the concept and key features of sustainable road construction globally and with reference to Sri Lanka. Following that, an expert interview and a survey were used to continue the study using a mixed research approach. Expert interviews and questionnaire surveys were conducted as the data collection method. The data analysis was done through manual content analysis and Relative Important Index (RII) techniques.

The findings revealed what are the existing sustainable features in Sri Lankan Road construction and its advantages and disadvantages. Then identify challenges and opportunities of Sri Lankan Road construction for sustainable development. Thus, the applicability of existing sustainable features to Sri Lankan Road construction shall be reviewed further in empirical research.

***Keywords**: Road construction, Sustainable features, Sri Lankan Road construction*

1. Introduction

The construction sector is frequently considered the engine that causes economic growth due to its strong backward and forward connections with other sectors. Increased construction activity on the other hand is thought to have negative economic, social, and environmental consequences (Balaban, 2012). According to Horvath (2004), environmental assessment is complicated because it covers a wide range of societal infrastructure components and facilities, including residences, commercial buildings, transportation, government, and military installations, roads, bridges, utilities, ports, and all public and private sector projects. Infrastructure and road construction projects, in general, are connected with a large number of emissions that vary from the commencement of project execution until the demolition stage (Marzouk et al., 2017). However, road infrastructure projects are difficult and vital measures for a country's social and economic development (Pilger et al., 2020). All sorts of roads, facilities, structures, signage and markings, and electrical systems are part of the road infrastructure, and they are all required for safe, trouble-free, and effective traffic flow (Ivenova & Masarova, 2013). Furthermore, when considering the life cycle of roads, primary energy consumption is linked to the use of electricity for road lighting and the usage of natural gas, diesel, and gasoline for construction equipment. The implementation of numerous construction operations such as earthmoving, truck transit on unpaved roads, crushing, material manufacture, and the operation of diesel-powered equipment has significant effects on the environment and human health through air pollution (Giunta, 2020). Furthermore, dust emissions of road construction depend on the construction processes, duration, equipment, plants, and quantity of material employed and transporting and handling methods. Therefore, to protect the global nature, significant changes are necessary to do further with fewer impacts.

Different advantages can be achieved through sustainable construction. Luther (as cited in Shurrab, Hussain & Khan, 2018) states the benefits of sustainable development as environmental, economic, and social. Furthermore, increased air and water quality, reduced energy usage, and reduced water consumption are all environmental benefits. Reduced operating and maintenance expenses, greater sales price, and improved health and comfort are all economic benefits. Typically, road design is based on technical and economic factors, with other factors such as social and environmental implications being overlooked (Machi et al., 2017). To achieve long-term sustainability in road building, measures such as environmental management, water-sensitive urban planning, advanced and recycled materials, and environmentally responsible project management and construction are required (Thorpe, 2012). Moreover, when consider economic sustainability of roads it is required to be built and managed within the budget and provide economic profit.

In Sri Lanka, rapid industrialisation in both the public and private sectors has resulted in pollution (Zubair, 2001). International Conference on Real Estate Management and Valuation (ICREMV, 2017) states government infrastructure projects are another trend in the Sri Lankan construction industry. The value of work done on roads and railroads is higher than all other types of construction, according to the final report of the Survey of Construction Industries in Sri Lanka 2017/2018 (2020). As a result, road construction represents a large portion of the Sri Lankan construction industry. Thus, investigation of the existing sustainable features introducing sustainable development for road construction is very important to avoid environmental, economic, and social issues relating to the construction industry. To attain this aim, the study had to address the following objectives:

1. Review the sustainable features normally used in the world for road construction
2. Review the advantages and disadvantages of sustainable road construction and identify challenges and opportunities globally and with reference to Sri Lanka
3. Investigate the existing sustainable features in the Sri Lankan Road construction.

2. Literature Review

A. Why need sustainable development

Pollution of the environment is a major problem all over the world, and it has a significant impact on human health. Pollution can be caused by both human and natural sources (Fereidoun et al., 2007). The construction and materials industries provide physical and biological support to one of the world's largest natural resource exploiters (Spence & Mulligan, 1995). McGeehin, Qualters, & Niskar, (2004) reported that Cancer, birth abnormalities, and asthma affect a significant portion of the population in the United States, and many of these disorders are linked to environmental exposures. According to estimates of global pollution, building and construction activities are responsible for 23% of air pollution in cities, 50% of climate change through gases, 40% of drinking water pollution, 50% of landfill pollution due to construction activities, and 50% of ozone depletion pollution (Brown & Bardi, 2001). Construction activities can harm the environment by destroying natural flora, water bodies, natural sand hills, gardens, and parking places, as well as causing damage to plant roots, root destruction, and dam damage. As a result, construction pollution has an impact on all humans, animals, the environment, and the natural ecosystem (Jain, Gupta, & Pandey, 2016). When it comes to water pollution, heavy diesel vehicles, paints, and solvents are left on site, and garbage is dumped illegally and mixed with rainwater, and waste is washed away by rain and mixes with water bodies, increasing water ecotoxicity (Cole, 2000). Construction waste is not properly treated and managed; one of the results is water pollution (Jain, Gupta, & Pandey, 2016). Water contamination is the main cause of death in humans all over the world. Water pollution also has an impact on our oceans, lakes, rivers, and drinking water (Scipeeps, 2009). Water contamination has an impact on soil and vegetation health and quality (Carter, 1985). Some water pollution impacts can be seen right away, while some of the water pollution effects couldn't be demonstrated immediately (Ashraf et al., 2010).

Traffic is the most significant source of air pollution. Pollution caused by traffic is becoming widely available in urban areas. CO, NO2, and PM are examples of such pollutants (Jung, Mehta, and Tong, 2018). Polluted air contains fewer or more hazardous materials, pollutants, or contaminants and that create a hazard to public health (Smith, 2007). Heavy dust production during construction has a significant influence on human health since it causes illnesses such as silicosis and lung cancer in those who work in this environment (Jain, Gupta, & Pandey, 2016).

The noise generated by heavy machine activities during the construction process is also a significant problem that has a negative influence on workers and nearby communities. It also raises the likelihood of sleeplessness, eye discomfort, high blood pressure, and stress issues. However, noise pollution increases due to increases of transportation vehicles in the development of urbanisation and industrialisation (Jain, Gupta, & Pandey, 2016). Cities with significant levels of pollution are placed on red alert in these countries, and they must focus on the impact of construction and find a solution. Construction pollution can be mitigated at this time if construction practices are changed (Jain, Gupta, & Pandey, 2016).

B. Road construction

Road infrastructure projects are time-consuming and essential to a country's social and economic development (Pilger et al., 2020). Soil sub-grade strength and traffic load are the two most significant parameters that influence pavement design (Bezabih & Chandra, 2009). In the past, roads were built entirely of stone, gravel, and sand, with water acting as a binding agent to level the surface and give it a polished appearance. Flexible and rigid pavements are the two types of pavements that are commonly known (Jain, Joshi, & Goliya, 2013; Mohod & Kadam, 2016). The following Table: 2, describes the difference between rigid pavement and flexible pavement.

Table 1: Difference between rigid pavement and flexible pavement

Flexible Pavement	Rigid Pavement
1. Subgrade deformation is transferred to the upper layers 2. Design based on the component layers' load-distribution properties 3. The flexural strength of flexible pavement is poor. 4. The load is passed from one grain to the next via grain-to-grain contact. 5. Have a low completion cost but a high repair cost 6. Have a short lifespan (High Maintenance Cost) 7. Surfacing cannot be installed directly on the subgrade; therefore, a subbase is required. 8. There are no thermal stresses created since the pavement can contract and expand freely. 9. There is no requirement for expansion joints. 10. The road's strength is mainly dependent on the subgrade's strength.	1. The deformation of the subgrade is transferred to the top layers. 2. Create a design based on the load-distribution properties of the component layers. 3. Flexible pavement has a low flexural strength. 4. The weight is transferred from one grain to the next by making contact with it. 5. Have a cheap cost of completion but a high cost of repair 6. Have a limited life expectancy (High Maintenance Cost) 7. Surfacing should never be applied to the subgrade directly. 8. Thermal stresses are more difficult to create because concrete has a limited ability to contract and expand. 9. An expansion joints are needed. 10. The road's strength is less dependent on the subgrade's strength.

11. The surfacing must be rolled. 12. Within 24 hours, the road can be used for traffic. 13. Frictional force is reduced in the subgrade and is not transferred to the top layers. 14. Oils and some chemicals cause damages	11. There is no need to roll the surfacing. 12. The road cannot be used until it has been cured for 14 days. 13. There is a lot of friction. 14. Oils and greases do not cause any damage.

C. Sustainable Road construction in Sri Lanka

Sustainable features normally used in Sri Lanka for road construction materials used

- Alternative materials

Soil stabilisation is currently used in road construction in Sri Lanka. A number of studies have developed new biological materials and methods to improve the strength of soils without the use of chemical binders like cement. Furthermore, industrial wastes like fly and bottom ashes are frequently used to reduce the amount of cement in concrete mixtures or soil stabilisation operations (Lee et al., 2019). Cement stabilised Rammed Earth is one such alternative construction material with a better probability of long-term sustainability. CSRE has been successfully used in Sri Lanka and many other nations for a number of uses and another problematic application of CSRE is in the construction of road pavements (Kariyawasam & Jayasinghe, 2016). Because of their great strengthening efficiency and low environmental impact, xanthan gum biopolymer is used as an alternative material for road construction (mostly shoulders and subbases) in Sri Lanka and other countries with similar climates and socioeconomic situations (Lee et al., 2019).

The most environmentally friendly road paving material is cement blocks. Although the initial cost is higher than other types of paving materials, the overall cost is lower. A pavement material that requires fewer maintenance tasks would be preferred (Mampearachchi & Gunatilake, 2013). Embankment filling can be done with coal ash. The use of coal ash in the road sector will improve not only the material shortage for road building but will also decrease the environmental impact caused by ash disposal issues. When compared to most European countries, where coal ash has been successfully used the use of coal ash for road construction in Sri Lanka is negligible (Ariyarathne, 2016).

- Recycled materials

Road construction materials such as reclaimed concrete and demolition waste are currently not widely available in Sri Lanka (Gobieanandh & Jayakody, 2016). To improve their performance in pavement sub-base applications, some recycled concrete and demolition materials, such as crushed bricks, may need to be combined with other durable aggregates (Arulrajah et al.,2011). The use of various types of concrete and demolition materials (recycled concrete aggregates, crushed bricks, and reclaimed asphalt pavement) in the base and sub-base layers of roadways has proven to be a great alternative to natural aggregates without sacrificing infrastructure performance (Vieira & Pereira, 2015).

COWAN center, a major recycling company in Galle, provided recycled concrete and demolition materials. The COWAM Center is Sri Lanka's first venue for sustainable construction waste management. Crushing demolished building trash, screening, and subsequent removal of pollutants such as reinforcement, paper, and other materials provide recycled concrete and demolition waste (Gobieanandh & Jayakody, 2016). In general, the use of recycled concrete and demolition materials in the construction industry is progressing quickly in some nations, but more slowly in others. Recent studies have demonstrated the feasibility of using concrete and demolition materials as recycled aggregate and its acceptable performance. Demolition concrete is a low-cost, ecologically friendly alternative that promotes long-term sustainability (Katkar, 2017).

D. Advantages and disadvantages of sustainable road construction in Sri Lanka

- Advantages of sustainable road construction in Sri Lanka

The most common technique of dealing with concrete and demolition waste is to dump it in landfills, which is posing an environmental risk. As a result, using recycled material in road construction will provide significant environmental and economic benefits. When compared to natural aggregates, using concrete and demolition waste would significantly lower costs because it is readily available and abundant, and it would also benefit the environment significantly by reducing quarry mining (Gobieanandh & Jayakody, 2016). The reuse of these materials helps to alleviate some of the current concerns with waste generation and natural resource extraction. Waste prevention, energy conservation, natural mineral resource conservation, and landfilling avoidance could all provide further benefits (Jayakody, Gallage, & Ramanujam, 2019). Coal ash has a low unit weight, which helps to reduce the settlement of embankments constructed on poor-bearing-capacity soil. Construction of a road embankment using coal ash is less difficult than utilising natural soil and it saves both time and money (Ariyarathne, 2016). These advantages include a reduction in the usage of virgin resources and a reduction in the environmental effect of waste disposal (Gidley & William, 1984).

- Disadvantages of sustainable road construction in Sri Lanka

Sustainable technologies are more expensive than traditional technologies (Athapaththu & Karunasena, 2018).

E. Challenges and opportunities of sustainable road construction in Sri Lanka

In 2007, the Sri Lankan Ministry of Environment and Natural Resources (MENR) introduced National Sustainable Development Strategies as a country-based and country-owned system for sustainable development (as cited in Athapaththu & Karunasena). Two socially responsible organisations that promote sustainable construction are the Green Building Council and the Sustainable Energy Authority. The current Acts fail to achieve true objectives of sustainable construction. While there are some provisions for environmental sustainability in construction, there are insufficient provisions for social and economic sustainability. The real roadblocks are political or external factors that prevent such laws and regulations from being updated (Athapaththu & Karunasena, 2018).

Contractors play a critical role in supporting sustainable construction by reducing negative consequences on the environment and society while increasing economic gains (Tan, Shen, & Yao, 2011). Contractors, on the other hand, face difficulties due to a lack of resources, technical skills, difficulty in achieving quality and profitability, a lack of understanding of sustainable features, a lack of appropriate building rules, and expensive capital expenses (Pitt et al., 2009). With rates that include expenditures for sustainability, a contractor cannot compete in competitive bidding. Contractors are unwilling to provide projects in a sustainable manner if clients do not require it since they would lose bidding competition (Athapaththu & Karunasena, 2018).

3. Methodology

The research methodology is a set of guidelines for achieving the study's goals by structuring the activities as they are outlined during the research process (Smith, Lowe, & Thorpe, 2002). However, for this study, a quantitative approach was adopted in order to identify the existing sustainable features of Sri Lankan Road construction. Closed-ended questions were used to validate the sustainable features of road construction, challenges, and opportunities identified through the literature review. Therefore, the purpose of having a questionnaire survey was to identify existing sustainable features for road construction in Sri Lanka.

The questionnaire survey was aimed at construction industry professionals with experience in both Sri Lankan Road construction and sustainable construction. As a result, non-random convenient sampling was chosen as the sampling method. At the end of the survey period, data were obtained from 35 of the 50 questionnaires given, yielding a response rate of 70%. This survey was performed to achieve the 3rd and 4th objectives, which aimed to identify the existing sustainable features in the Sri Lankan Road construction. The distribution of ages of the respondents, academic qualifications and the year of experience they engage in the construction industry was demonstrated in Table 2. Accordingly, 94.3% of respondents had B.Sc. Degree and 5.7% of respondents had master's degrees. Among the respondents, 54.3% were in age Between 25 -35 years and 25.7% of respondents were in age less than 25 years. When considering the years of experience, most of the respondents had 1 -5 years of experience. All of these respondents were construction industry professionals such as engineers, quantity surveyors, architects, and project managers like that. The demographic distribution of the respondents is shown in Table: 2.

Table 2: Demographic distribution of the respondents

Variable	Category	Frequency	Percentage
Ages	Less than 25 years	9	25.7%
	Between 25 -35 years	19	54.3%
	Between 35 – 45 years	7	20%
	Above 45 years	0	0%
Year of experience	Less than 01 year	10	28.6%
	Between 01 – 05 years	12	34.3%
	Between 05 – 10 years	6	17.1%
	More than 10 years	7	20%
Academic qualific	Diploma	0	0%
	B.Sc. Degree	33	94.3%
	Master's Degree	2	5.7%
	Above Master's Degree	0	0%

ation			

The applicability of existing sustainable features in Sri Lankan Road construction was examined through the views of 35 experienced and qualified respondents in the Sri Lankan construction sector.

The level of applicability was determined using a five-point Likert scale: **1**-Strongly Disagree; **2**-Disagree, 3-Neutral; **4**-Agree; **5**-Strongly Agree. And a five-point Likert scale was employed, with **1**- Not applicable; **2**- Rarely applicable; **3**- Applicable in moderate level; **4**- highly applicable and **5**- Applicable in all times

The responses were used to score the discovered sustainable features, as well as their advantages, disadvantages, challenges, and opportunities, according to their level of applicability. In his study, Shash (1993) discovered that the Relative Importance Index (RII) is better for interpreting ranking data than indicators like mean and standard deviation. Furthermore, he defined RII as the weighted average of each factor divided by the dimensions' upper scale. The following equation is used to calculate the RII value of a certain collection of data.

$$RII = \Sigma PiUi/n\ (N)$$

Where;

[**n**- Number of participants; **Pi** -Participant's rank; **Ui**- Number of participants ranking project factor; **N**- Highest rank]

Table: 3 was used to identify the existing sustainable features in the Sri Lankan Road construction.

Table 3: Interpretation of RII values I

RII VALUE	INTERPRETATION
0-0.200	Strongly Disagree
0.200-0.400	Disagree
0.400-0.600	Neutral
0.600-0.800	Agree
0.800-1.000	Strongly Agree

4. Research Finding

A. Analysis of the Sustainable features normally used in Sri Lanka for road construction

The RII values for each sustainable feature normally used in road construction in Sri Lanka were calculated and ranked. The results of the analysis are shown in Table 4.

Table 4: Ranking of the existing sustainable features according to the RII values

Sustainable features normally used in Sri Lanka for road construction	RII	Rank
In Sri Lanka, various types of concrete and demolition materials (recycled concrete aggregates, crushed bricks, and reclaimed asphalt pavement) are used in the base and sub-base layers of roadways.	0.806	1
Sri Lankan construction industry has developed new biological materials and methods to improve the strength of soils without the use of chemical binders like cement	0.794	2
Cement blocks are most environmentally friendly road paving material used in Sri Lanka.	0.766	3
Industrial wastes like fly and bottom ashes are frequently used to reduce the amount of cement in concrete mixtures in Sri Lanka	0.754	4
Embankment filling can be done with coal ash. Sri Lanka uses coal ash for road construction embankment filling	0.720	5
Sri Lanka is having a significant process to waste management, including recycling construction waste	0.663	6
Cement Stabilised Rammed Earth is one such alternative construction material with a better probability of long-term sustainability in Sri Lanka	0.629	7
Locally accessible materials are clearly chosen for road construction in Sri Lanka	0.617	8
Sri Lanka use dust controlling methods for road construction	0.617	8
Sun energy harvesting, thermoelectric energy harvesting, geothermal energy harvesting, and composite energy harvesting can all be used to convert solar radiation, thermal gradients in pavement layers, and geothermal heat into useable energies. These methods are used in Sri Lanka	0.520	9
Xanthan gum biopolymer is used as an alternative material for road construction (mostly shoulders and subbases) in Sri Lanka because of their great strengthening efficiency and low environmental impact	0.451	10
Piezoelectric energy harvesters gather traffic-induced vibrations on pavements. This method is used in Sri Lanka	0.423	11

According to the ranking as shown in above Table:4, 'various types of concrete and demolition materials (recycled concrete aggregates, crushed bricks, and reclaimed asphalt pavement)' 'new biological materials and methods to improve the strength of soils without the use of chemical binders like cement' can be considered as most used sustainable features to Sri Lankan Road construction. Moreover, 'Cement blocks, Industrial wastes like fly and bottom ashes are frequently used to reduce the amount of cement in concrete mixtures, Embankment filling done with coal ash, waste management, Cement Stabilised Rammed Earth, locally accessible materials and use dust controlling methods for road construction presented nearly similar RII values, which had the high usage of Sri Lankan Road construction. 'Sun energy harvesting, thermoelectric energy harvesting, geothermal energy harvesting, and composite energy harvesting can all be used to convert solar radiation, thermal gradients in pavement layers, and geothermal heat into useable energies, 'Xanthan gum biopolymer is used as an alternative material for road construction and 'Piezoelectric energy harvesters gather traffic-induced vibrations on pavements' had the lowest RII values compare to others.

B. Analysis of the advantages of sustainable road construction in Sri Lanka

The RII values were calculated and ranked for each advantage of sustainable road construction in Sri Lanka. The findings of the analysis are shown in Table: 5.

Table 5: Ranking of the advantages according to the RII values

Advantages of sustainable road construction in Sri Lanka	**RII**	**Rank**
The reuse of these materials helps to waste prevention, energy conservation, natural mineral resource conservation, and landfilling avoidance	0.863	1
Sustainable road construction includes a reduction in the usage of virgin resources and a reduction in the environmental effect of waste disposal	0.834	2
The use of recycled material in road construction will provide significant environmental and economic benefits	0.823	3
When compared to natural aggregates, using concrete and demolition waste would also benefit the environment significantly by reducing quarry mining	0.800	4
When compared to natural aggregates, using concrete and demolition waste would significantly lower costs because it is readily available and abundant	0.783	5
Construction of a road embankment using coal ash is less difficult than utilising natural soil and it saves both time and money	0.754	6
Coal ash has a low unit weight, which helps to reduce settlement of embankments constructed on poor-bearing-capacity soil	0.743	7

According to the ranking as shown in above Table: 5, the 'reuse of these materials helps to waste prevention, energy conservation, natural mineral resource conservation, and landfilling avoidance', 'reduction in the usage of virgin resources and a reduction in the environmental effect of waste disposal', 'Use of recycled material in road construction will provide significant environmental and economic benefits, 'when compared to natural aggregates, using concrete and demolition waste would also benefit the environment significantly by reducing quarry mining' can be considered as most common advantages of sustainable road construction. 'When compared to natural aggregates, using concrete and demolition waste would significantly lower costs because it is readily available and abundant', 'Construction of a road embankment using coal ash is less difficult than utilising natural soil and it saves both time and money and 'Coal ash has a low unit weight, which helps to reduce settlement of embankments constructed on poor-bearing-capacity soil showed almost similar RII values, which also can be considered as advantages of sustainable road construction.

C. Analysis of the disadvantages of sustainable road construction in Sri Lanka

The RII values were calculated and ranked for each disadvantage of sustainable road construction in Sri Lanka. The results of the analysis are shown in Table 6.

Table 6: Ranking of the disadvantages according to the RII values

Disadvantages of sustainable road construction in Sri Lanka	**RII**	**Rank**
High levels of investment are required to implement sustainable development	0.777	1
Sustainable technologies are more expensive than traditional technologies	0.754	2

According to the ranking as shown in above Table: 6, 'high levels of investment are required to implement sustainable development' and 'sustainable technologies are more expensive than traditional technologies' can be considered as disadvantages of sustainable road construction in Sri Lanka.

D. Analysis of the opportunities of sustainable road construction in Sri Lanka

The RII values were calculated and ranked for each opportunity for sustainable road construction in Sri Lanka. The findings of the analysis are shown in Table: 7.

Table 7: Ranking of opportunities according to the RII values

Opportunities of sustainable road construction in Sri Lanka	**RII**	**Rank**
Green Building Council and the Sustainable Energy Authority help to promote sustainable development	0.794	1
The National Sustainable Development Strategies introduce by Sri Lankan Ministry of Environment and Natural Resources (MENR) as a country-based and country-owned system for sustainable development helps to promote sustainable development	0.669	2

According to the ranking as shown in above Table: 7, 'Green Building Council and the Sustainable Energy Authority help to promote sustainable development' and 'The National Sustainable Development Strategies introduce by Sri Lankan Ministry of Environment and Natural Resources (MENR) as a country-based and country-owned system for sustainable development helps to promote sustainable development' can be considered as opportunities of sustainable road construction in the Sri Lankan context.

E. Analysis of the Challenges of sustainable road construction in Sri Lanka

The RII values were calculated and ranked for each challenge of sustainable road construction in Sri Lanka. The findings of the analysis are shown in Table: 8.

Table 8: Ranking of challenges according to the RII values

Challenges of sustainable road construction in Sri Lanka	**RII**	**Rank**
A lack of understanding of sustainable features	0.891	1

Challenges of sustainable road construction in Sri Lanka	**RII**	**Rank**
Contractors are unwilling to provide projects in a sustainable manner if clients do not require it since they would lose bidding competition	0.874	2
Sri Lanka lacks a type-specific environmental rating system for road construction	0.869	3
A lack of technical skills	0.851	4
Difficulty in achieving quality and profitability	0.794	5
A lack of resources	0.789	6
Expensive capital expenses	0.789	7
The current Acts fail to achieve true objectives of sustainable construction.	0.783	8
The real roadblocks are political or external factors that prevent such laws and regulations from being updated	0.760	9
A lack of appropriate building rules	0.743	10

According to the ranking as shown in above Table: 8, ‘A lack of understanding of sustainable features’, ‘Contractors are unwilling to provide projects in a sustainable manner if clients do not require it since they would lose bidding competition’, ‘Sri Lanka lacks a type-specific environmental rating system for road construction’, and ‘A lack of technical skills’ can be considered as main challenges of sustainable road construction in Sri Lanka. Moreover, ‘difficulty in achieving quality and profitability’, ‘A lack of resources’, ‘Expensive capital expenses’, ‘The current Acts fail to achieve true objectives of sustainable construction’, ‘The real roadblocks are political or external factors that prevent such laws and regulations from being updated’ and ‘A lack of appropriate building rules’ showed almost similar RII values, which were challengers of Sri Lankan sustainable road construction.

F. Analysis of the applicability of existing sustainable features to Sri Lankan Road construction

The RII values for existing sustainable features' applicability to Sri Lankan Road construction were calculated and ranked. The findings of the analysis are shown in Table: 9.

Table 9: Ranking of the applicability of existing sustainable features

The applicability of sustainable features to Sri Lankan Road construction	**RII**	**Rank**
New biological materials and methods to improve the strength of soils	0.766	1
Cement blocks	0.766	2
Concrete and demolition materials as an alternative material	0.754	3
Industrial wastes like fly and bottom ashes as an alternative material	0.737	4
Dust controlling methods	0.714	5

The applicability of sustainable features to Sri Lankan Road construction	RII	Rank
Embankment filling can be done with coal ash	0.651	6
Cement Stabilised Rammed Earth	0.600	7
Used local materials (materials which are available in construction area)	0.600	8
Energy harvesters (Sun energy, thermoelectric energy, geothermal energy, Piezoelectric energy and composite energy)	0.594	9
Xanthan gum biopolymer as an alternative material	0.463	10

According to the ranking as shown in above Table: 9,' New biological materials and methods to improve the strength of soils', 'Cement blocks', 'Concrete and demolition materials as an alternative material', 'Industrial wastes like fly and bottom ashes as an alternative material' and 'Dust controlling methods' can be considered as most practicable sustainable features to Sri Lankan Road construction. Moreover, 'Embankment filling can be done with coal ash' and 'Cement Stabilised Rammed Earth', and 'Used local materials', presented nearly similar RII values, which had high applicability of Sri Lankan Road construction. 'Energy harvesters (Sun energy, thermoelectric energy, geothermal energy, piezoelectric energy, and composite energy)' and 'Xanthan gum biopolymer as an alternative material' had the lowest RII values compared to others.

5. Discussion

The intention of the questionnaire was to identify the existing sustainable features in the Sri Lankan Road construction. According to the findings, the level of usage was considered to rank the sustainable features. When considering the RII values, it is perfect that all the sustainable features have an average level of usage having RII value more than 0.5 excluding Xanthan gum biopolymer and piezoelectric energy harvesters gather traffic-induced vibrations on pavements. This suggested that all the identified sustainable features excluding those two sustainable features available in the Sri Lankan Road construction. Furthermore, according to the findings, the advantages of sustainable road construction were ranked according to the level of applicability. When considering the RII values, it becomes evident that all of the advantages have an average level of applicability of higher than 0.7. As per the results, the disadvantages of sustainable road construction were ranked with the level of applicability. When the RII values are analysed, it becomes evident that all of the disadvantages have an average level of applicability of higher than 0.7.

According to the findings, the opportunities for sustainable road construction were ranked according to their level of applicability. When considering the RII values, it's evident that all of the opportunities have a high level of applicability, with an RII value greater than 0.7. The level of applicability of the sustainable features was ranked based on the findings. When considering the RII values, it's evident that all of the sustainable features, with the exception of Xanthan gum biopolymer as an alternative material, have an average level of applicability of more than 0.5. This indicates that, with the exception of these sustainable features, all of the identified sustainable features can be implemented in the Sri Lankan context without any doubt.

6. Conclusion

Environmental pollution is a huge issue around the world, and it has a substantial impact on human health. The concept of sustainable development connects development and the environment. Sustainable construction can provide a number of advantages and have three components such as social, economic, and environmental. Furthermore, improved air and water quality, lower energy consumption, and lower water consumption are environmental advantages. Economic benefits include lower operating and maintenance costs, higher sales prices, and increased health and comfort. Road design is typically based on technical and commercial considerations, with social and environmental consequences being disregarded. Therefore, this paper's aim of introducing sustainable development for road construction in Sri Lanka was achieved through accomplishing three main objectives.

A comprehensive study of the sustainable features normally used in the world for road construction was reviewed through the literature. Sustainable features normally used in the world for road construction were identified over two main categories such as the material used and the construction process. Furthermore, under material used category identified three main sustainable features such as recycled material, alternative materials, and used local materials (materials that are available in the construction area). Identification of these key features provided the foundation for this paper. Advantages and disadvantages of sustainable road construction were identified according to the identified sustainable features used in the world for road construction. The reuse of these materials helps to waste prevention, energy conservation, natural mineral resource conservation, and landfilling avoidance, reclaimed roadways lower material transportation distances then further savings in the transportation industry, and when compared to natural aggregates, using concrete and demolition waste would significantly lower costs are some of the identified advantages globally and with reference to Sri Lanka. Identified disadvantages are a significant amount of money is required and High levels of investment are required to implement sustainable development.

When considering the opportunities for sustainable road construction, as per the analysis, the green Building Council and the Sustainable Energy Authority help to promote sustainable development, and The National Sustainable Development Strategies introduced by the Sri Lankan Ministry of Environment and Natural Resources were identified as opportunities of sustainable road construction. However, in expert interviews, respondents mentioned that still no contribution or procedure from the government and other relevant authorities to sustainable development for road construction in Sri Lanka. Various types of concrete and demolition materials (recycled concrete aggregates, crushed bricks, and reclaimed asphalt pavement) used for road construction, cement blocks pavement, and industrial wastes like fly and bottom ashes are frequently used to reduce the amount of cement, embankment filling can be done with coal ash, waste management, cement Stabilised Rammed Earth, use dust controlling methods, xanthan gum biopolymer, used local materials and renewable energy were identified through literature review. As per the questionnaire analysis, xanthan gum biopolymer and piezoelectric energy harvesters gather traffic-induced vibrations on pavements were not used in Sri Lanka.

References

Ariyarathne, B., 2016. *The utilisation of coal ash for road construction in Sri Lanka,* s.l.: Road Development Authority.

Arulrajah, A., Piratheepan, J., Aatheesan, T. & Bo, M. W., 2011. Geotechnical properties of recycled crushed brick in pavement applications. *Journal of Materials in Civil Engineering,* 23(10), p. 1444–1452.

Ashraf, M. A., Maah, M. J., Yusoff, I. & Mehmood, K., 2010. Effects of polluted water irrigation on environment and health of people in Jamber, district Kasur, Pakistan. *International Journal of Basic & Applied Sciences,* 10(3), pp. 37-57.

Athapaththu, K. I. & Karunasena, G., 2018. Framework for sustainable construction practices in Sri Lanka. *Built Environment Project and Asset Management.*

Balaban, O., 2012. The negative effects of construction boom on urban planning and environment in Turkey: Unraveling the role of the public sector. *Habitat International,* 36(1), pp. 26-35.

Bezabih, A. G. & Chandra, S., 2009. Comparative study of flexible and rigid pavements for different soil and traffic conditions. *Journal of the Indian Roads Congress,* pp. 154-162.

Brown, M. T. & Bardi, E., 2001. *Handbook of Energy Evaluation.* s.l.:s.n.

Carter, F., 1985. Car pollution problems in post-war Czechoslovakia. *Pollution Problem Transactions of the Institute of British Geographers,* 10(1), pp. 17-44.

Cole, R. J., 2000. Building environmental assessment methods: Assessing construction practices. *Construction Management and Economics,* 18(8), pp. 947-957.

Fereidoun, H. et al., 2007. The effect of long-term exposure to particulate pollution on the lung function of Tehranian and Tanzanian students. *Pakistan journal of physiology,* 3(2).

Gidley, J. S. & William, A., 1984. Environmental aspects of waste utilization in construction. *Journal of Environmental Engineering,* 110(6), p. 1117–1133.

Giunta, M., 2020. Assessment of the environmental impact of road construction: Modelling and prediction of fine particulate matter emissions. *Building and Environment,* Volume 176.

Gobieanandh, V. & Jayakody, S., 2016. *Evaluate the strength of cement-treated recycled construction and demolition aggregates as a pavement material.* Kandy,,.n., pp. 61-67.

Horvath, A., 2004. Construction materials and the environment. Volume 29, pp. 181-204.

Ivanova, E. & Masarova, J., 2013. Importance of road infrastructure in economic development and competitiveness. *Economic and Management,* 18(2).

Jain, G., Gupta, V. & Pandey, M., 2016. Case study of construction pollution impact on the environment. *International Journal of Emerging Technologies in Engineering Research,* 4(6), pp. 1-4.

Jain, S., Joshi, Y. P. & Goliya, S. S., 2013. Design of rigid and flexible pavements by various methods & their cost analysis of each method. *Journal of Engineering Research and Applications,* 3(5), pp. 119-123.

Jayakody, S., Gallage, C. & Ramanujam, J., 2019. Performance characteristics of recycled concrete aggregate as an unbound pavement material.

Jung, S. J., Mehta, J. & Tong, L., 2018. Effects of environmental pollution on the ocular surface. *The Ocular Surface,* 16(2), pp. 198-205.

Kariyawasam, K. & Jayasinghe, C., 2016. Cement stabilized rammed earth as a sustainable construction material. *Construction and Building Materials,* Volume 105, p. 519–527.

Katkar, B. S., 2017. Utilization of recycled demolition waste aggregates in previous concrete. *International Journal of Innovation Research on Science and Engineering,* 3(5), pp. 167-171.

Lee, S. et al., 2019. Xanthan gum biopolymer as a soil-stabilization binder for road construction using local soil in Sri Lanka. *Journal of Materials in Civil Engineering,* 31(11).

Mampearachchi, W. K. & Gunatilake, M. M. D. V., 2013. *A sustainable road construction material for low volume roads,* s.l.: s.n.

Marzouk, M., Abdelkader, E. M., El-zayat, M. & Aboushady, A., 2017. Assessing environmental impact indicators in road construction projects in developing countries. *Sustainability,* 9(5).

McGeehin, M. A., Qualters, J. R. & Niskar, A. S., 2004. National environmental public health tracking program: Bridging the information gap. *Environmental Health Perspectives,* 112(14), pp. 1409-1413.

Mood, M. V. & Kadam, K., 2016. A comparative study on the rigid and flexible pavement: A review. *Journal of Mechanical and Civil Engineering,* 13(3), pp. 84-88.

Pilger, J. D. et al., 2020. Environmental impacts and cost overrun derived from adjustments to a road construction project setting. *Journal of Cleaner Production,* Volume 256.

Pitt, M., Tucker, M., Riley, M. & Longden, J., 2009. Towards sustainable construction: promotion and best practices. *Construction Innovation,* 9(2), pp. 201 - 224.

Research and Professional Development Center, University of Sri Jayawardena Pura, Sri Lanka, 2017. *Smart real estate toward unmet socio-economic needs.* s.l., university of Sri jayawardanapura, Sri Lanka, pp. 1-207.

Scipeeps, 2009. Effects of Water Pollution.

Shurrab, J., Hussain, M. & Khan, M., 2019. Green and sustainable practices in the construction industry: A confirmatory factor analysis approach. *Engineering, Construction and Architectural Management,* 26(6), p. 1063 – 1086.

Smith, K. R., 2007. *Energy and health,* s.l.: s.n.

Smith, Lowe & Thorpe, 2002. Management Research: An Introduction.

Spence, R. & Mulligan, H., 1995. Sustainable development and the construction industry. *Habitat Internationnal,* 19(3), pp. 279-292.

Tan, Y., Shen, L. & Yao, H., 2011. Sustainable construction practice and contractors' competitiveness: A preliminary study. *Habitat International,* Volume 35, pp. 225- 230.

Thorpe, D., 2012. *Evaluating factors in sustainable road construction and management - a life cycle approach.* Edinburgh, Association of Researchers in Construction, pp. 1235-1244.

Torres-Machi, C., Pellicer, E., Yepes, V. & Chamorro, A., 2017. Towards a sustainable optimization of pavement maintenance programs under budgetary restrictions. *Journal of Cleaner Production,* Volume 148, pp. 90-102.

Vieira, C. S. & Pereira, P. M., 2015. Use of recycled construction and demolition materials in geotechnical applications: A review. *Resources, Conservation and Recycling.*

Zubair, L., 2001. Challenges for environmental impact assessment in Sri Lanka. *Environmental Impact Assessment Review,* 21(5), pp. 469-478.

Authors Biography

M. G. K Hasanthika is a graduate student at the Department of Building Economics, University of Moratuwa, Sri Lanka. Her research interests include sustainable development, civil construction, and road construction.

V. Disaratna is a senior lecturer in quantity surveying attached to the Department of Building Economics, University of Moratuwa, Sri Lanka. He completed of B.Sc.(QS) Hons, MBA (UK), RICS PM (Dip) (UK) and member of A.I.Q.S SL, MRICS, ACIArb, SEDA (UK). He has published in leading journals and conferences in the field of built the environment, with over 20 refereed papers related to Project Management, Procurement-Bidding/ Risk, Contracts administration, Claims management, Strategic marketing, Maintenance Management, and Workplace issues, Industrial training, and trainee and employer expectations.

H. C. Victar is a graduate student at the Department of Building Economics, University of Moratuwa, Sri Lanka. Currently, he is following his Master (By Research) Degree in the same department. He has published journal and conference papers. His research interests include Circular Economy, Waste Management and Quantity Surveying.