Health, safety, and environmental impacts of road infrastructure projects in Sri Lanka; Impact analysis on ongoing and temporarily suspended road works

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ABSTRACT

Road networks are considered to be the primary mode of transport in Sri Lanka. Road infrastructure plays an important role in the country's economy. The work environment of construction projects is generally considered one of the most dangerous places for work. The current economic recession faced by Sri Lanka has led to the temporary suspension of road works. The aim of this study is to identify the main types of health, safety, and environmental issues that occur in the construction of different ongoing and suspended road infrastructure projects in Sri Lanka. Questionnaire surveys, discussions, and site observations were carried out to collect data from road projects of different classes. Data analysis was done using the SPSS (Version 28) statistical software. The findings of the research indicated that vehicle collisions were the most common type of occupational accident faced in road construction in Sri Lanka. The fatality rate caused due to poor health and safety management of road construction works was compared with the construction of buildings and other developing countries. The results obtained from the study also identified that negligence was the main factor that influenced low safety standards on-site, which in turn impacted the performance of the construction project. Measures taken by construction companies of different grades to improve health and safety standards were also studied in the research. It was also evident that suspended road projects had an adverse effect on the environment, as it was seen that these sites possessed a loss in diversity, high chances of sediment erosion, and a rise in mosquito breeding locations. The findings of this research highlight the need of prioritizing health and safety in road projects and also enable construction companies to handle construction work in a way that minimizes environmental damage occurs.

KEYWORDS: *Health, safety, road construction, Sri Lanka*

1 INTRODUCTION

The working conditions of the construction industry are quite harsh and require a crucial amount of physical strain to be exerted by each working individual. The majority of construction workers use hazardous tools and equipment. Over the years, construction has undergone several improvements and transpositions but is still considered a risky profession due to the high number of accidents that take place. It has been found that the construction industry accommodates an exceptionally greater number of severe accidents or deaths in comparison to other industries of Sri Lanka (Rameezdeen et al., 2006). Furthermore, a study conducted by the National Institute for Occupational Health and Safety (NIOSH) of the United States shows that from 2003 to 2017, 67 percent of work-related deaths occur in the construction industry (*Highway Work Zone Safety | NIOSH | CDC*, 2021).

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Accidents in the field of construction can take place due to many reasons. Falls from heights, being struck by or against objects or machinery, electrical-related injuries, transport-related injuries, fire, and explosion are some of the key accidents identified in construction sites (Ahamed et al., 2011).

OHS issues do not only affect the office staff and laborers of the construction firm but also the public residing in the vicinity of the road construction project (Xing et al., 2018). The lack of information regarding occupational accidents in Sri Lanka is a grave and critical issue.

The aim of conducting this research was to identify the main types of health, safety, and environmental issues that occur in the construction of different ongoing and suspended road projects in Sri Lanka.

Unfortunately, Sri Lanka is currently battling the worst economic recession since its independence (McLoughlin, 2022). Due to this current economic crisis faced by Sri Lanka, many road and bridge infrastructure projects have been temporarily suspended. The effect of the ongoing economic recession on the health and safety aspects of such projects needs to be investigated.

2 METHODOLOGY

2.1 Study Area

The study was limited to Expressways (Class E), Main roads (Class A and B), and Secondary Minor Roads (Class C and D). The projects included in the study were managed by construction companies that acquired grades of CS2, CS1, C1, C2, C4, and SP1 in highway and bridge construction that have been implemented by the Construction Industry Development Authority of Sri Lanka (CIDA). Data were collected from a total of 52 road and bridge construction projects. Out of which 27 projects were ongoing, and 25 projects were suspended.

2.2 Primary and Secondary Data Collection

This research involves the collection of primary data. Data was obtained through questionnaire surveys, conducting interviews with compliant persons, and site observations. It focused on health and safety issues faced by the office staff of the construction firm, construction workers, and neighboring communities. The questionnaire consists of open-ended and close-ended questions. Linkert scales were used in the questionnaires so that the respondents can simply choose an option that best aligns with their perspective. The questionnaires were divided into three sections. The first section gathered general information related to the road project. Company grade, name of the project, duration of the project, road class, and project area information were included in this section. The next section was based on personal information such as the designation and years of experience of the respondent. The third section of the questionnaire included details such as the number of accidents that have been recorded on-site, penalties imposed on employees that violate the health and safety rules and regulations, PPE provided on-site, training programs conducted for employees, health issues faced on-site, and impacts of accidents and injuries to the project or construction firm. The questionnaire also comprised of questions where respondents have the ability to express their own views on improvements in the health and safety of road projects. The responses obtained from the surveys were analyzed using excel functions and SPSS software to obtain the perspective on the health and safety of road construction from officials of the construction companies, laborers as well as the neighboring communities. Secondary data was collected through a comprehensive literature survey from journals, health, and safety standards, books, government websites, and official web pages.

2.3 Data Analysis

2.3.1 Population and Sample

According to the Planning Division of the Road Development Authority (RDA), a total of 122 roads and bridges are under construction in Sri Lanka. Equation (1) was used to obtain the sample size of the study (Latupeirissa et al., 2021).

$$n = \frac{N}{(1+Ne^2)} \quad (1)$$

Where: n = Sample size; N = Size of the population; and e = Desired margin of error which is considered to be 10%. According to Equation (1), a sample size of 55 is required.

2.3.2 Shannon-Weiner Index

SWI which is also known as the Shannon Diversity Index was used to estimate the diversity of the plant species available in the site area of suspended road infrastructure projects (Rain 2022). A high value of SWI indicated that the site possessed a high plant diversity, which is considered as a sign of an unpolluted environment (Das et al., 2012).

$$H = -\sum_{i=1}^{n}[(p_i)\ln(p_i)] \quad (2)$$

2.3.3 Soil Runoff

The empirical formula founded by Inglis and Desouza in 1929 was used to calculate the annual runoff due to rainfall at the suspended site locations (Praveen et al., 2016).

$$R = \frac{(P-17.8)\times P}{254} \quad (3)$$

Where: R = Annual runoff; and P = Annual rainfall.

2.3.4 Corrosion Rate

The corrosion rate of steel reinforcement bars was calculated using Equation (4) in order to identify the severity of the environmental impacts caused due to the products emitted by the corrosion of steel (Umeozokwere et al., 2016).

$$C_R = \frac{k\times\Delta w}{A\times T\times\rho} \quad (4)$$

Where: C_R = Rate of corrosion; Δw = Weight loss due to corrosion; A = Exposed surface area; ρ = Density of mild steel = 7.86 g/cm^3, T = Time of exposure; k = Constant for unit conversion = 8.76 x 10^{-4}.

2.4 Correlations and Significance

Standard statistical tests such as One-Way ANOVA and Pearson Correlation were used to understand the relationship between variables. The significant difference between two or more variables was evaluated using one-way ANOVA. Pearson correlation was used to identify the linear relationship between two variables. IBM SPSS V28 was used to conduct these statistical tests. A significance level of $P < 0.05$ was considered when conducting the analysis for all cases.

3 RESULTS AND DISCUSSION

3.1 General Statistics of the Samples

The study included data collection related to health and safety aspects followed in ongoing and suspended road infrastructure projects. Sri Lanka has classified roads into different classes. Figure 1 shows the road classes covered in the study and the percentage of responses obtained from each road class.

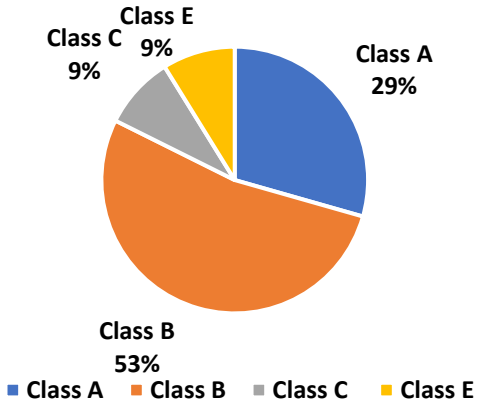

Figure 1: Responses obtained from different road classes.

This study is focused on 52 road and bridge construction sites that are ongoing and suspended due to the current economic recession. The names and locations of projects will not be mentioned due to confidentiality.

3.2 Health and Safety Aspects of Ongoing Road Infrastructure Projects

3.2.1 Accidents and Injuries Caused due to Poor Health and Safety Standards

Falls from height, vehicle collisions, electric shocks, fire-related injuries, and struck-by or struck-against objects are some of the common accidents that occur in the construction industry. Figure 2 shows the average number of accidents that occur in a project per year due to poor safety standards in ongoing road construction works. There is a significant difference between the type of work-related accidents and the frequency of occurrence ($P = 0.02 < 0.05$).

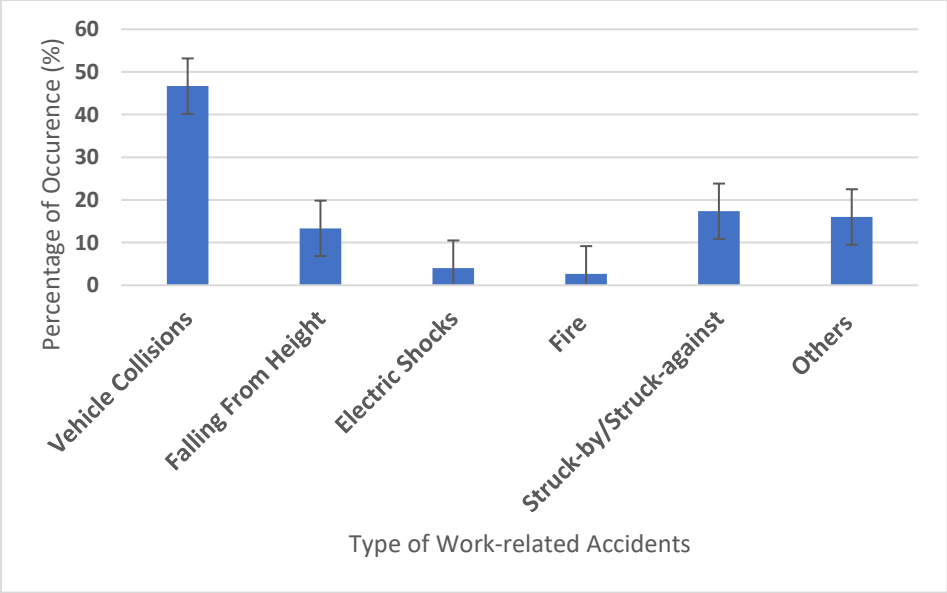

Figure 2: Percentage of occurrence of work-related accidents

Previous studies stated that most fatalities in road construction projects occur due to the collision of vehicles (Shah and Alqarni, 2018). The study conducted on road construction projects in Sri Lanka showed similar results. According to Figure 2, the most occurring accidents on road projects are vehicle collisions. These collisions include construction workers being struck by a vehicle or mobile equipment and vehicles colliding with other vehicles due to the traffic caused by the ongoing road construction works. It can be seen that 47% of the work-related accidents occur due to collision of vehicles, followed by 17% of the accidents caused due to being struck by or struck-against various objects, and 13% of the

accidents resulted due to falling from height. Accidents caused due to the collision of vehicles can occur due to various reasons. The use of mobile equipment that is not in good working condition, hiring of unqualified flagmen, and drunk driving are the main reasons that lead to vehicle collisions (Pegula, 2013).

Many studies done in the past have proven that falling from heights is the most common accident that occurs in building constructions. The review conducted by Nadhim et al. in 2016 stated that masons, carpenters, and roofers were the most common trades exposed to falling from heights. A building's structural height and increasing wind pressure at top levels are some of the factors that lead to falling from heights (Nadhim et al., 2016). Since road projects possess low structures compared to buildings and as it does not involve roofing the percentage of occurrence of falling from heights is less in the construction of roads.

3.2.2 Personal Protective Equipment (PPE)

As stated in the article written by Jhonson in the year 2020, the use of correct PPE can be used to protect construction staff members and laborers from various health and safety risks that can occur at the site (Johnson, 2020). It was observed that only 72% of the ongoing road projects involved in the study provided all personnel at the site with safety helmets, safety boots, high-visibility jackets or safety vests, and gloves. However, 28% of the construction projects did not provide the staff and laborers with all the basic PPE, which indicates poor health and safety standards followed on the site. Discussions held with the safety managers of ongoing projects revealed that gloves, safety harnesses, and safety goggles are provided to the workers on request, depending on the work they are engaged in. It was also noted that the use of earplugs and dust masks is not seen among workers involved in road projects in Sri Lanka. This can lead to serious illnesses such as hearing loss and lung cancer.

3.2.3 Penalties Imposed for Violating OHS Standards

It was observed that certain construction companies imposed penalties on staff members and construction workers for not adhering to the safety rules of the site. As discussed with Project Managers, Safety Officers, and Engineers at the site it was stated that penalties were mainly imposed on workers for not wearing proper PPE which is been provided to them for free. This is a good practice followed by most of the road construction projects included in the study to reduce the number of fatal and non-fatal injuries occurring on-site. Table 1 shows the penalties imposed for various projects.

Table 1: Penalties Imposed

Penalty Imposed	Number of Projects
Rs. 500 per labourer. Rs. 1000 per office staff	21
Suspension after 3 warnings	5
Immediate Suspension	1
Salary deduction of 3%-5%	2
Salary deduction of 5 %	2
2 written warnings, 5% salary deduction for 3rd warning, suspension after 3rd warning	1
No Penalty	7

Table 1 shows that 54% of the construction companies involved in the study levied Rs. 500 per laborer and Rs. 1000 per office staff member for violating health and safety standards. Hence, it can be stated that the most common type of penalty imposed was charging Rs. 500 from laborers and Rs. 1000

from office staff members. However, it was seen that certain projects imposed penalties on laborers only. This is an unfortunate biased action followed by many industries today.

In most developing countries, the main types of penalties imposed due to violating standard health and safety rules are fines and imprisonment. In the year 2015, Slowey stated that the owner of the construction company in California and the project manager of the relevant project was sentenced to two years of prison after a construction worker was killed due to a collapse of a concrete retaining wall. Furthermore, a project manager of another construction company in the United States was charged $ 1.8 million for exposing workers to asbestos (Slowey, 2015). In addition, breaching safety standards in India will result in three-month imprisonment or a fine of INR 2000 from all employees involved in the affair (Labor Department, Government of Uttar Pradesh, 2022). These studies show that the level of penalty imposed depends on the severity or the nature of the violation. However, through the results obtained in this study, it is evident that construction companies involved in road and bridge projects in Sri Lanka do not implement this method. This in turn may have a negative effect on the health and safety aspects of the project as the severity of violations is not being addressed.

3.2.4 Factors that influence Health and Safety Standards of Ongoing Road Projects

The opinions of office staff members such as Engineers, Technical Officers, Quantity Surveyors, and Safety Officers of construction companies on the factors that influence the health and safety of road construction projects are shown in Figure 3.

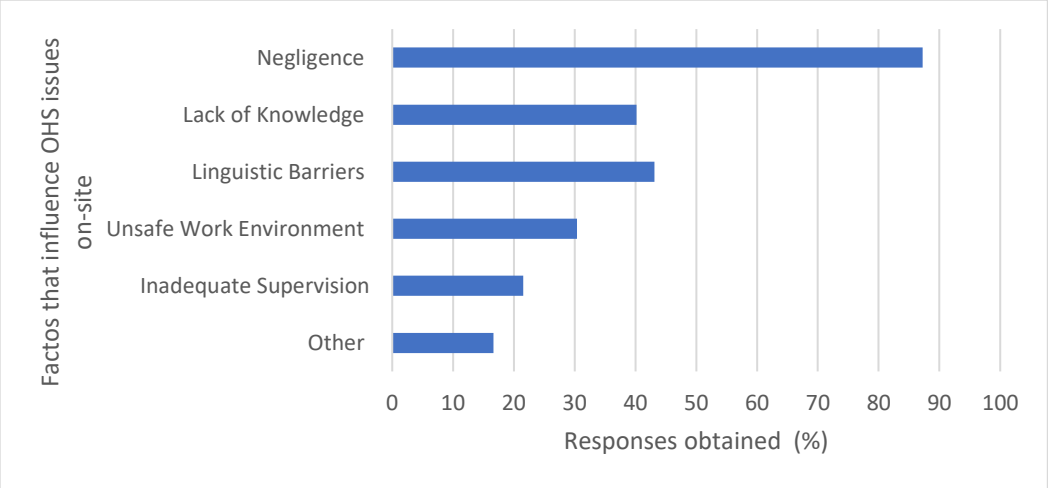

Figure 3: Office staff members' view on factors that influence the health and safety of road projects

The results in Figure 3 show that 87% of the respondents think that the negligence of workers, as well as site supervisors, accounts for the cause of accidents and injuries that take place on-site. This was observed during site visits, as there were unattended power cables lying on the site premises. This act of negligence may cause serious damage to lives as employees can get electrocuted if there are any shortages in the power supply. Furthermore, a study conducted by Ahamed et al. in 2011, also established that the negligence of employees is the most common root cause of construction accidents.

43% of the respondents also stated that linguistic barriers have also affected the safety on-site. Due to the multicultural nature of Sri Lanka, people from different ethnic backgrounds can be found in the working environment. Thereby, different languages are spoken in the working environment, which sometimes proves to be a challenge as not all workers are fluent in all languages, and this can result in miscommunication and misunderstanding. For example, if safety instructions are exchanged between a supervisor and a laborer that suffer the challenge of a language barrier, the instructions may not be delivered properly, resulting in dire consequences.

Lack of knowledge is another major factor raised by 40% of the respondents. Past studies have identified that workers were unaware of the safety rules followed by the construction company. In

addition, the study stated that workers showed a dislike towards wearing PPE since they did not possess a good understanding of the risks associated with not wearing PPE while at work (Vitharana et al., 2015). Furthermore, unsafe working environments and inadequate site supervision also influence poor health and safety standards in road construction projects.

3.2.5 Impacts of Poor Health and Safety Standards on Road Projects

Poor health and safety standards not only impact the lives of people but also has an indirect influence on the performance of the construction project. The office staff members of different road works expressed their views on the impacts of poor health and safety on the project in the following manner.

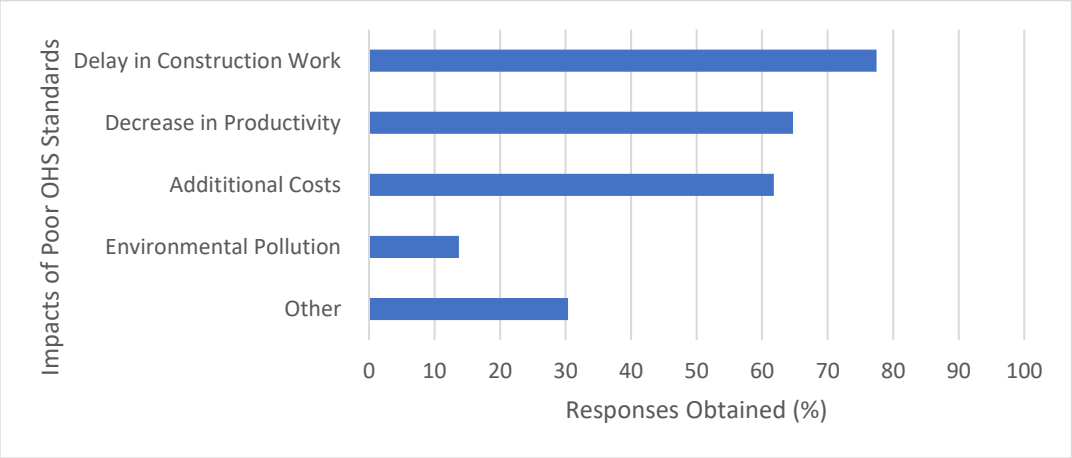

Figure 4: Staff members' view on the impacts of poor health and safety standards followed in road projects

As seen in Figure 4, delay in construction works received 77% responses, followed by 65% responses for the decrease in labor productivity. A study conducted by Handoko et al. in the year 2020, has proved that practicing good health and safety standards on-site has a positive effect on improving the performance of employees. For example, the use of safety helmets during construction work, not only protects the worker from head injuries but also protects the worker from the scorching sun. This in turn will enable the worker to focus and complete a wider range of work.

Maintaining good health and safety standards on-site is a cost for the construction company. However, the cost incurred will be greater if any work-related accidents occur (Handoko et al., 2020). It has also been stated that the compensation paid for a fatality caused due to a work accident in Sri Lanka will be increased to 2 million LKR (Ministry of Labor and Foreign Employment, 2022).

Even though environmental pollution received a low number of responses, it is evident that construction activities cause dust and noise pollution. Dust emissions resulting from road construction activities such as excavation, drilling, concreting, and material transportation are proven to have an adverse effect on the environment as well as the human lungs which may lead to diseases such as silicosis, bronchitis, and asthma (Xing et al., 2018).

3.2.6 Health Issues Faced by Staff Members and Neighborhood Communities

In addition to minimizing the probability of the occurrence of work-related accidents on-site, the construction company involved in the road project is also obliged to maintain the health of employees as well as the neighboring communities. Figure 5 shows the percentage of the employees of the construction companies and the neighbors residing in the vicinity of the road project that has been affected by poor health and safety standards practiced on the site.

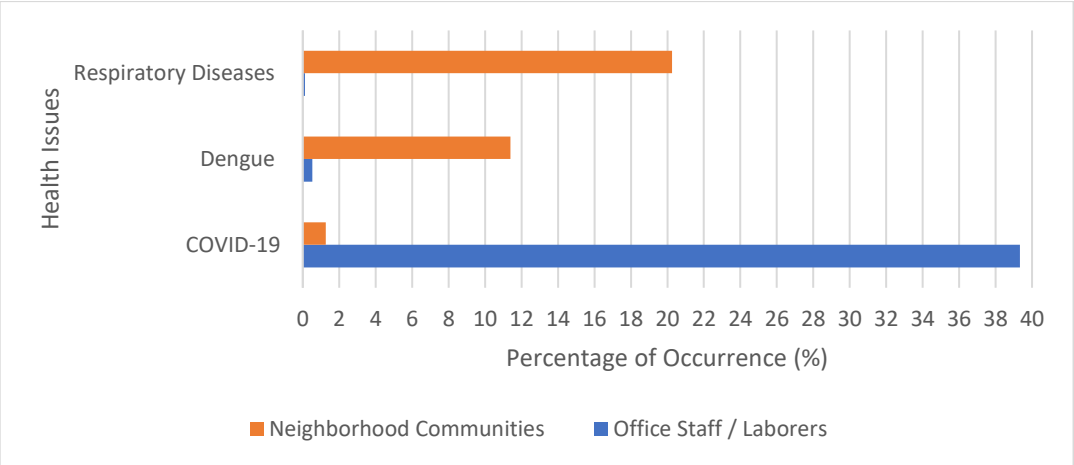

Figure 5: Health Issues faced by employees of the construction company and neighborhood community

It can be observed that 39% of the employees involved in the ongoing road projects involved in the study were impacted by the COVID-19 virus. Furthermore, 20% of the respondents stated that they have been affected by various respiratory diseases such as asthma due to the dust emitted by nearby construction activities. The results shown in the graph of Figure 5 also state that neighbors suspect the spread of dengue is due to site conditions. However, the low number of dengue cases that have been reported on-site does not tally with the neighbors' view. Therefore, further investigations must be carried out to find the reason that caused this discrepancy.

3.3 Health and Safety Aspects of Suspended Road Infrastructure Projects

Around 70% of construction projects including highways and roads have been haltered until there is an increase in the state's revenue (Jayasinghe, 2022). Since the suspended road and bridge projects did not involve any contract staff members or laborers, it was observed that the health and safety impacts were at a minimum. The only people that could have been impacted by the health and safety of these projects were those who entered the site premises for non-work-related reasons. Discussions held with residents in the vicinity of the suspended projects revealed that children and teenagers in the area use the site premises to play cricket and various other games. Broken-down safety signs and barricades were observed in almost 80% of the suspended road projects that were visited. Therefore, the unauthorized entry of persons should be prevented in order to avoid unfortunate fatal or non-fatal accidents from occurring. In addition, accumulated stagnant water was seen in all the suspended sites that were visited. The accumulated stagnant water was calculated as a percentage of the total site area and the following results were obtained.

Table 2: Percentage of accumulated stagnant water with respect to site area of suspended road projects

Percentage of accumulated stagnant water with respect to total site area	Number of suspended road and bridge projects
0 – 10%	15
10% - 20%	8
20% - 30%	2

This accumulated stagnant water aids the spread of the dengue virus. According to the studies conducted by the World Health Organization(WHO), it has been stated that an infected *Aedes Aegypti* has the ability to fly up to 400m during the day (*Dengue and Severe Dengue*, 2019). The average distance to the nearest residence of suspended road works was calculated to be 365m which is less than the distance flown by an infected mosquito. Hence, this can lead to the spread of the dengue virus within the neighborhood communities. Therefore, necessary precautions must be taken by construction companies to avoid the spread of such deadly diseases.

3.4 Environmental Impacts of Suspended Road Infrastructure Projects

The impact on the progress of road construction projects due to the current economic crisis in Sri Lanka is highly evident as it is a prominently discussed topic today. However, unfortunately, no one has raised their concerns about the environmental impacts caused due to the suspension of these construction projects. Table 3 shows the main environmental impacts that could occur due to unattended construction sites.

Table 3: Key Environmental Impacts and their Frequency of Occurrence

Key Environmental Impacts	Frequency of Occurrence
Soil erosion due to rainfall	4%
Soil erosion due to wind	4%
Reduction in plant diversity	28%
Contamination of groundwater	20%

3.5 Quantification of Environmental Impacts of Suspended Projects

3.5.1 Shannon Weiner Index

A rough estimate of the SWI was calculated for the suspended projects in order to check the diversity and richness of the site. The results showed that suspended road and bridge construction sites possessed low SWI values, which means these sites were found to have low diversity. It was also observed that the richness levels of the suspended construction sites were low. The low richness and diversity can result in low quality of ecosystem's services such as maintaining the soil conditions, purifying the soil that is run through soil, and also the supply of food (Rafferty, 2019).

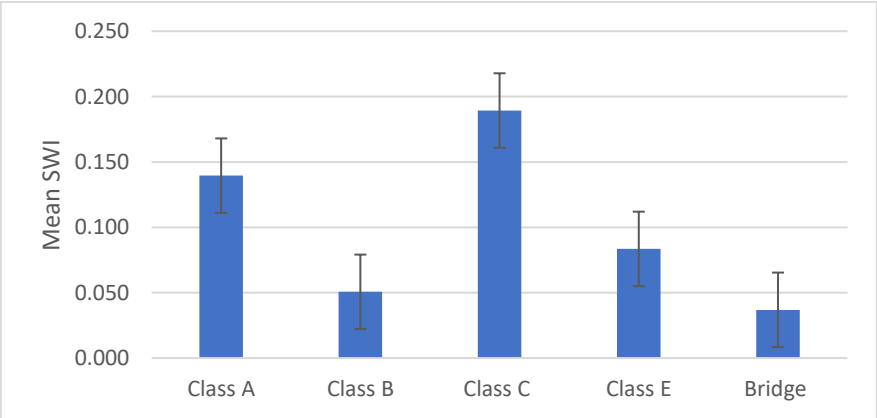

Figure 6: Comparison of Road Types and SWI

The average SWI of construction projects of bridges and different road classes is shown in Figure 6. There is little or no significance between the mean SWI and road types ($P = 0.052 > 0.05$).

3.5.2 Iron Input to the Environment due to Corrosion

During site visits, it was observed that many suspended road projects possessed steel formwork and reinforcement bars that have been corroded with time. 12mm, 16mm, 20mm, and 32mm mild steel reinforcement bars are commonly used in road construction works. Therefore, the corrosion rate for these commonly used bar sizes was calculated to analyze the effect of corrosion on the environment. Table 4 shows the rough estimate calculated for corrosion rates of different bar diameters.

Table 4: Corrosion rates of different bar sizes

Bar Diameter (mm)	Corrosion Rate (10^{-5} mm/week)
12	6.99
16	5.24
20	4.19
32	2.62

A study conducted by Javaherdashti in the year 2000, also stated that a tonne of steel can turn into rust in 90 seconds. Escaping products from corrosion can result in environmental pollution, causing dangers to human health. Furthermore, the damage done to materials due to corrosion can result in safety concerns in the final product as well as additional costs for the construction company (Javaherdashti, 2000).

3.5.3 Soil Erosion due to Rainfall

Rain hitting on bare soil can result in soil erosion. The annual runoff levels in the suspended site locations were calculated in order to analyse the probabilities of soil erosion. The calculated runoff levels ranged from 101.47cm to 505.82cm. The mean annual runoff was obtained to be 192.55cm.

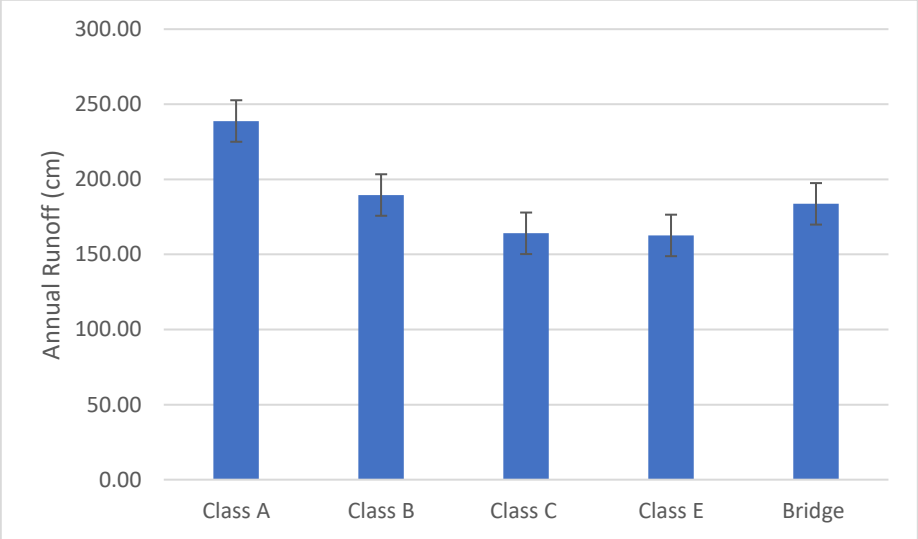

Figure 7: Comparison of Road Types and Runoff

Figure 7 shows the annual mean runoff due to rainfall of bridges and different road classes. The results obtained indicated that there was no significant difference between the runoff levels and respective road classes ($P = 0.604 > 0.05$).

4 CONCLUSION

Poor health and safety practices in road and bridge infrastructure projects have led to an unfortunate number of construction accidents and health issues in Sri Lanka. The aim of this study was to identify the main types of health, safety, and environmental issues that occur in the construction of different ongoing and suspended road projects in Sri Lanka and to perform an analysis of how the stakeholders of different road works have been impacted.

According to the study conducted on ongoing road projects, it was established that officials of the construction company, laborers, and residents living in close proximity to the site are the main stakeholders affected by poor health and safety management in road construction sites. The results obtained from the analysis indicated that vehicle collisions were the most common type of accident

faced in ongoing road and bridge projects, followed by struck-by/struck-against objects and falling from heights. According to the responses obtained, COVID-19 was the main health issue faced by office staff members and laborers of the construction firm. However, the responses obtained from neighborhood communities stated that respiratory diseases were the main health-related issue faced by them. It was also proven that the poor health and safety standards followed on-site caused delays in construction work, a decrease in worker productivity, additional costs for the construction company, and also increased environmental pollution. Furthermore, the study also recognized that construction companies with higher grades took precedence in taking necessary measures to improve the health and safety conditions of the site. The measures taken include conducting toolbox meetings, providing good site supervision, providing appropriate and good quality PPE, and using machinery and equipment that are of good working condition.

The ongoing economic crisis faced by Sri Lanka resulted in the temporary suspension of highway and bridge projects. The health and safety aspects of such projects were analyzed by visiting these sites. The study established that suspended road projects had a long-term impact on the environment. The quantification of these environmental impacts resulted in addressing the possibility of sediment erosion, biodiversity issues, and the breeding of mosquitoes.

The unfavorable impacts on human lives, the environment, and the economy caused due to poor health and safety conditions followed by construction firms can be mitigated or minimized if necessary measures are taken by the involved parties. The findings of the research highlight the need of prioritizing health and safety in road projects in order to improve the productivity of the construction industry of Sri Lanka.

Furthermore, the consideration given to environmental issues that have arisen due to the suspended road projects is low. Therefore, the outcomes of this study will enable construction companies to handle construction work in a way that minimal environmental damage occurs.

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