Management of Environmental Risks in Highway Construction Projects in Sri Lanka

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Abstract

Purpose: Environmental Risks (ERs) are critical to any Highway Construction Project (HCP). One of the main contracting parties responsible for ERs is the contractor. Hence, it has been crucial to look into ways to control ERs in HCPs from the contractor's perspective. This research is aimed at investigating how ERs can be managed in HCP in Sri Lanka.

Design/Methodology/Approach: A quantitative research approach with three rounds of Delphi was used. Statistical techniques were used to analyse and validate the ERs, the parties to whom the risks were to be allocated, and Risk Management (RM) measures identified from the empirical data collection.

Findings: The study reveals the 11 most significant ERs for HCP. Further, the most significant ERs in HCP were mainly found to be the responsibility of contractors in Sri Lanka. 24 most appropriate risk response measures determined, 13 were found to be common measures that could be used to manage two or more risks, while the remaining 11 were unique to specific risks.

Originality/value: Overall, this research determines the most significant ERs in HCP, the best risk allocation among the parties, and appropriate risk-handling strategies and measures for each significant ER. Additionally, the study addresses the demand for ER management in HCP.

Key Words: Environmental Risks, Highway Construction Projects, Risk Management

1. Introduction

According to the Environmental Risk and Management Guideline, risk is referred to as the combination of potential consequences of a hazard and their likelihoods or probabilities of occurrence (Gormley-Gallagher *et al.*, 2011). Risks have always been a part of human activity, and different risks, such as epidemics and crop failures, have always made economic operations more difficult (Kosyakova, 2019). Environmental risks are among the most important of these risks because of the fast industrialisation, urbanisation, and consumption growth that have caused major environmental issues in the global context (Xu *et al.,* 2017). On the other hand, the rapid rate of urbanisation throughout many regions of the world has sparked an increase in demand for new construction projects, which is boosting the growth of the construction sector, particularly the development of infrastructure (Ladan, 2019). Therefore, the construction of infrastructure could potentially have an effect on the environment and raise the probability of environmental risks (Liang *et al.*, 2022).

Infrastructure investments account for 31% of global capital investment (Abeysekara *et al.*, 2021). Among them, highways are a critical that serves as the backbone of a nation, allowing for the rapid and secure transportation of goods and people and promoting economic and social development (Radzi *et al.*, 2022). In Sri Lanka, the Road Development Authority (RDA) owns 277 km of highway roads and plans to complete the construction of another 241.8 km within the next five years (RDA, 2020). However, since Highway Construction Projects (HCPs) are geographically dispersed, most of the studies have confirmed that the risk involved in those projects is higher than other projects (El-Sayegh and Mansour, 2015; Reilly and Brown, 2004) due to higher capital expenditure, higher complexity, and economic, social, and political issues (Ahmadi *et al.*, 2017; Molenaar and Wilson, 2009). As a result, there is an increased danger of environmental harm in the context of infrastructure development, including highway construction, as well as associated risks including habitat destruction, soil erosion, and pollution (Handa *et al.*, 2019).

The environmental effects of road projects have been exacerbated as a result of the rapid growth of infrastructure, particularly the construction of highways (Li *et al.*, 2022). The principal categories of Environmental Risks (ERs) in road projects may include dust, toxic gases, noise, and solid and liquid waste (Walimuni *et al.*, 2017). Further, biodiversity is harmed as a result of road construction projects throughout the construction time, and it may continue to be harmed as a result of human activity after the construction phase ends (Alamgir *et al.*, 2017; Laurance *et al.*, 2009; Trombulak and Frissell, 2000). Compared to all the risks in road construction, ERs are directly caused by the major drawbacks in road construction projects themselves (Coffin, 2007; Creedy *et al.*, 2010; Laurance *et al.*, 2015).

The Sri Lankan government has established a number of programmes to hasten the development and improvement of expressway infrastructure in order to deal with the export of resources and related regional growth (RDA, 2020). Although there are a lot of activities and enormous amounts of money being spent on HCPs in Sri Lanka, there is very little systematic knowledge concerning the ERs associated with these projects (Karunathialke *et al.*, 2021). Only a few researchers have previously concentrated their attention on ERs. Moreover, addressing environmental risks during highway construction projects is crucial to safeguard the environment, advance sustainable development, and uphold international environmental commitments (Newman *et al.*, 2012). On the other hand, when considering global issues, understanding environmental risk factors is essential when making decisions aimed at preserving the public's health, and investment in programmes and actions aimed at reducing environmental dangers could help lessen the strain on healthcare systems around the world (Rojas-Rueda *et al.*, 2021). Therefore, the purpose of this research was to examine the management of ERs in Sri Lankan HCPs.

To achieve this aim, the study involved the following research questions:

- Q1: What are the most significant ERs in HCPs?
- Q2: What would be the most appropriate allocation of significant ERs among contracting parties involved in HCPs?
- Q3: What are the most suitable risk-management strategies to handle the most significant ERs in HCPs?

Further, risks in construction projects can arise from a number of sources and vary in their frequency as well as their impact (Rauzana, 2013). Thus, this study adds to the body of knowledge by examining the main ERs in HCP based on the likelihood that various ER factors or hazards occur (Frequency of Occurrence) and their potential impact (Level of Impact) on the environment. The study findings can be applied to any other nation based on their distinctions in social, political, geographic, cultural, and technological spheres. However, they are mostly connected to the Sri Lankan context.

2. Literature Review

2.1. Risks and Risk Management in the Construction Industry

Construction work is carried out in a complex environment, and hence, risks are unavoidable (Divya and Pabhu, 2019; Renault and Agumba, 2016; Sharma and Gupta, 2019). The term "risks" in construction refers to the potential loss/impact on the project deliverables at any stage of its life cycle due to the likelihood of the occurrence of an event (i.e., hazard) of a particular magnitude (Makombo, 2012; Szymanski, 2017). To elaborate further, when an event (i.e., a hazard) combines with vulnerable conditions, "risk" transpires (Agrwal and Blockley, 2007). Risks can transpire in construction projects in a variety of ways, including financial losses, property damage, personal injury, and failure to receive document approval in accordance with local authorities and legal requirements (Gain *et al.*, 2022). Although it is difficult to control all potential risks in a construction project (El-Sayegh, 2008), the need to control them in construction is extremely essential (El-Sayegh and Mansour, 2015). Therefore, Risk Management (RM) is a very vital process to handle the risks in construction projects as well as manage and control deliverables throughout the project life cycle (Mishra and Malik, 2017). Risk Management (RM) is an organised approach that provides a proper means of preventing and mitigating/reducing the risks experienced in the construction sector (Olamiwale, 2014). Henceforth, RM is defined as a systematic process that identifies, analyses, and responds to risks (Gain *et al.*, 2022; Liu *et al.*, 2007; Yoon *et al.*, 2015).

2.2. Risk Management Process

Identification and Classification: Risk identification is the first step in the RM process, which entails identifying all potential risks (Gain *et al.*, 2022; Perera *et al.*, 2009; Renault and Agumba, 2016) and classifying them in order to organise the various risks that could have an impact on a project (Rezakhani, 2012). Mainly, the risks can be classified into areas related to the environment, politics, economy, and law, and those are the most significant risks that need to be reduced for the success of the projects (Bahamid and Doh, 2017; Renault and Agumba, 2016; Rostami and Oduoza, 2017). Among the above classifications, ERs are significant since they carry the highest level of risk compared to the other risk categories (Jayasudha and Vidivelli, 2016). The identified risks then need to be allocated, which is the process of transferring risk from one party to another through contract terms (Zhang *et al.*, 2016).

Allocation: A correctly drafted contract will ensure proper risk allocation (Hiyassat *et al.*, 2022). Improper risk allocation can have a negative impact on the client-contractor relationship as well as reduce project performance (Zhang *et al.*, 2016). Generally, contractors are allocated the majority of risks since they are involved in most of the duties throughout the construction phase, including technical, financial, legal, environmental, and organisational obligations (Akintoye *et al.*, 2003; Perez *et al.*, 2017).

Analysis: Risk analysis is regarded as the examination of unfavourable events (hazards), and vulnerabilities to determine the risk levels. (Marco and Thaheem, 2013). This analysis enhances the decision-making process and offers extra justifications that aid in choosing the best risk response strategies and measures.

Responses: Responding to risks will enhance opportunities to achieve the project objectives since it involves developing options and/or actions to handle the risks (Morote and Ruz-Vila, 2011). A risk response strategy is evaluated to determine its effectiveness in risk response, and then, for each risk response strategy, the optimal risk response measures are identified and implemented (Fateminia *et al.*, 2019). Risk response measures are the process of determining risk response plans and identifying measures to deal with risks, aiming to increase opportunities and reduce any threats to project objectives (Wang and Chaou, 2003). Risk response can be categorized into four strategies: transfer, avoidance, reduction (mitigating), and retention (acceptance) (Serpella *et al.*, 2014; Albogamy and Dawood, 2015).

2.3. Risk Response Measures

Risk transfer occurs by transferring the risk to another entity or sharing the risk with a third party (Popvici, Fernando, and Navarrete, 2016). In generic construction, risk can be transferred to the different contract parties, including subcontractors, insurance companies, and those contractors involved in the design and build of construction work (Perera *et al.*, 2009; Yoon *et al.*, 2015). Additionally, quoting a high bid price for a tender and including all necessary criteria in the bid, choosing an alternative construction technique to maintain the construction schedule, and changing the plans and designs can all be considered as effective risk avoidance strategies in the construction industry (Ahmadi *et al.*, 2017; Yoon *et al.*, 2015). Further, risks can also be accepted by minimising unnecessary delays in decision-making, accepting all the results arising due to risks, and keeping a contingency plan (Naji and Ali, 2018; Perera *et al.*, 2020). Since some of the risks are predictable, they can be mitigated through measures such as effective communication with other contractual parties and providing education and training to the workers of the organization. However, as per previous researchers, these measures can also be used to transfer, avoid, accept, and mitigate risk when working with HCPs (Azhagarsamy *et al.*, 2021; Albogamy and Dawood, 2015).

2.4. Environmental Risks in the construction industry

ERs occur due to a wide range of off-site activities such as mining, manufacturing, and transportation of materials and components, land acquisition, project design, and onsite activities. Air pollution, water pollution, traffic problems, and the generation of construction waste are some of the ERs (Ametepey and Anash, 2014). Table I lists the literature findings on ERs that exist in general and in road construction projects, which include potential environmental-related losses and impacts (ERs) as well as various events (hazards) and vulnerable conditions that could lead to ERs, as have been identified from the existing literature.

Insert Table I

These factors were identified as the same as those mentioned in the original sources of reference. As per the above table, many authors have identified consequences such as air and water pollution, adverse weather conditions, the introduction of chemical pollution, noise and other atmospheric effects, road-related mortality, barrier effects, exotic species invasions, and disruption to the physical environment as key ERs associated with HCPs.

2.5. Environmental Risks in Highway Construction Projects

HCPs are riskier and subjected to various risks such as technical, site, and commercial risks, as well as external risks such as environmental, political, and socioeconomic risks (El-Sayegh and Mansour, 2015). Highway construction results in the direct removal and destruction of existing ecosystems as well as the alteration of regional landforms (Walia *et al.*, 2017). Also, the development of roads alters the topography in a variety of ecological ways, which are indicated by both abiotic and biotic elements of terrestrial and aquatic ecosystems (Hansen *et al.,* 2005). In particular, road engineering in HCPs damages surface vegetation and wildlife; excavations in HCPs expose soil and create erosion due to changes in ground conditions; and HCPs will produce chemical pollution, noise, and other consequences (Xiaofeng *et al.*, 2020). Also, the roadbed preparations in HCPs mostly result in linear cutting, which includes the vegetation and soil changes brought on by roadbed excavation or landfill, the obstruction of animal migration, and the modification of surface runoff (Xv, 2009). Therefore, ERs and social repercussions can be highlighted as the most pressing issues in HCPs (Badalpur and Nurbakhsh, 2021; Karunasena *et al.*, 2017). Therefore, finding the environmental effects of highway construction has been an urgent need in developing countries like Sri Lanka (Karunathilaka *et al.*, 2021).

2.6. Necessity for Environmental Risks management in Highway Construction Projects in Sri Lanka

Highways are a vital piece of infrastructure that may directly address issues of a serious nature and foster economic growth (Xiafeng *et al.*, 2021). The total length of all roads on the globe in 2018 was 64,285,009 km, including 411,853 km of expressways and 63,873,156 km of regular roads (SCMO, 2019). Furthermore, Sri Lanka also has an extensive network of roads totalling 116,000 km, including 12,380 km of expressways that are managed by the national government (RDA, 2020). However, as the majority of HCPs in Sri Lanka are financed with foreign funds (Asia Development Bank, 2018), it is the duty of the government to ensure that these funds are used wisely and that the appropriate time, cost, and quality criteria are met (Hettiarachchi, 2011). Hence, managing risks in highway projects is extremely important for Sri Lanka.

Further, one of the most significant forms of risk in HCPs is ERs (Ahmadi *et al.*, 2017; Alamgir *et al.*, 2017), and the same issue can be acknowledged for Sri Lankan HCP. And also, highway risks have become an ecological boundary, altering biological flow and landscape pattern and affecting the spread of species (Xiaofeng *et al.*, 2021). However, these risks vary from country to country due to transportation, political, cultural, and socio-economic difficulties (Kerur and William, 2012). Therefore, it is essential to identify and examine the risks associated with the host country in order to create an acceptable risk assessment methodology (Guzin and Almula, 2014). Risk assessments are therefore crucial in projects involving the construction of highways in order to avoid negative effects caused during the project life cycle (Azhagarsamy *et al.*, 2021).

Similarly, researchers have identified RM in road construction in general (Diab *et al.*, 2017; Shayan *et al.*, 2019), and some of them have concentrated on different risk types such as financial and economic risks (Nguyen *et al.*, 2020; Perera *et al.*, 2022); technical risks (Mishra and Adhikari, 2019; Sharaf and Abdelwahab, 2015); and social risks (Zhengji and Shen, 2010; Yuan *et al.*, 2018). Although there has been a lot of research on risk management in the construction sector, there has not been much written explicitly about project-type risk management in developing countries

(Chileshe and Awotunde, 2010). As a result, a limited amount of research is evident on addressing risks in HCPs (Ankit *et al.*, 2016; Azhagarsamy *et al.*, 2021). However, research on ERs associated with highway construction is exceedingly rare, both globally and in the Sri Lankan context (Alamgir *et al.*, 2017; Laurance *et al.*, 2015; Mann *et al.*, 2021). Thus, although managing ERs in highway construction is critical (Mann *et al.*, 2021), literature on ER management in HCPs is extremely rare, especially in Sri Lanka. Therefore, this has been the focus of this study. Furthermore, the Sri Lankan HCPs were particularly selected due to the complex and unique geological environment of Sri Lanka, which has been overlooked in the construction process, resulting in a slew of detrimental consequences.

This study is limited to the contractor perspective. In general, contractors may be held accountable for environmental harm caused by their work. When a contractor fails to complete their work properly while minimising environmental effects, this failure causes environmental harm (Environmental Risk Professional, 2020). In addition, generally, the responsibility of Environmental Impact Assessment is declared over the client and consultant. But this study deviates from the above concept and further confines itself to assessing the ERs from the contractor's perspective because, in Sri Lanka, it is mostly the contractor who is liable for environmental impact assessments and the client's responsibility in this regard is considered minimal. The allocation of risks can also change depending on viewpoints. For instance, the perspectives of the contractor and the client on risk allocation are different (Hiyassat *et al.* 2014). Thus, it is very important to take into account the viewpoint of the most appropriate party. As a result, the contractor is considered the main party who is primarily responsible for ERs, and the results are determined from his perspective.

3. Research Methodology

As per Smith *et al.* (2007), the nature of research questions themselves (i.e., "what," "who," "where," "how much," and "how many" types of questions) suggests the adoption of a quantitative approach to this study, where the accuracy of quantitative data is claimed to be extremely high (Islam and Nepal, 2016) compared to qualitative data due to the flexible examination of two variables: frequency of occurrence and level of impact. Further, the need for ranking the most significant ERs in highway projects advocates a quantitative approach for the study.

The Delphi method is a structured communication and consensus-analytical method (Chan *et al.*, 2001; Gohdes and Crews, 2004) that involves a group of experts who are expected to respond to non-leading, explicit statements in a series of iterations (rounds) with the goal of reaching consensus (Agumba and Mosunda, 2013; Holey *et al.*, 2007). On the other hand, this technique can be applied to the analysis of complex circumstances where large-scale quantitative data is insufficient to reveal the depth of tacit knowledge and necessitates the comprehension of nuanced expert opinion (Grisham, 2009). Therefore, the Delphi technique was chosen as the primary data collection method. Additionally, Xia and Chan (2012) have suggested that, in quantitative approaches, proper conclusions can be reliably drawn from more than two Delphi rounds. Therefore, this research used three Delphi rounds in order to accomplish the research aim more accurately and to achieve consensus. Details of the Delphi rounds and phases under each round are presented below:

3.1. Delphi Round 1

The ERs identified from the literature review were validated in Delphi Round 1 with respect to HCP. The respondents were asked to either add to the existing risks, remove them from the existing ones, or make the necessary modifications considering the contractor's perspective for highway construction in Sri Lanka using their practical experience. Furthermore, a number of elements had comparable meanings because the risks were listed in the same way as they were found in the original sources of reference. As a result, the respondents were also instructed to suggest risks with comparable meanings in order to split or amalgamate them since some variables of different nature were placed under one context to prevent misunderstandings or errors in further rounds. They were provided with the list of ERs identified from the literature review in relation to generic and road construction projects. The risks that were validated by more than 80% of the respondents were carried on to the next Delphi round of the study.

3.2. Delphi Round 2

Phase I

During phase I of Delphi Round 2, the respondents were asked to rank the ERs that were reviewed in Delphi Round 1, considering the frequency of risk occurrence and level of impact. Probability and impact assessment, which has been a frequently used analytical method in RM in previous studies (Lavanya and Malarvizhi, 2008; Sun *et al.*, 2008), was utilised to generate the severity index of risk and analyse the ranking (LaConte, 2018; PMI, 2021; Perera *et al.*, 2014).

$$\boldsymbol{S_j^i} = \propto_j^i \boldsymbol{\beta_j^i} \qquad \text{(Equation 1)}$$

$$\boldsymbol{RS^i} = \frac{\sum_{j=1}^{n} \boldsymbol{S_j^i}}{\boldsymbol{n}} \qquad \text{(Equation 2)}$$

Where n – Number of responses, S_j^i – Evaluation of risk severity of i^th^ risk by the j^th^ respondent, $\propto_j^i$ – Evaluation of frequency of risk occurrence by the j^th^ respondent, β_j^i – Evaluation of the Level of risk impact by the j^th^ respondent, RS^i– Risk Severity Index for the i^th^ risk.

Phase II

During this stage, respondents were asked to identify the party to whom the ERs could be assigned with reference to the risks identified during the literature study and Delphi round 1.

Phase III

Phase III was carried out to validate the risk strategies and response measures that were identified from the literature review to determine their applicability to managing the ERs in HCP in Sri Lanka from the contractor's perspective. Respondents were instructed to validate the strategies and response measures based on their agreement and disagreement with each risk response measure, as well as to include new strategies that had not been discovered in the literature review in relation to generic construction projects. The risk strategies and response measures that were validated by more than 80% of respondents were carried on to the next Delphi round of the study.

3.3. Delphi Round 3

Phase I

In Phase I, the respondents were instructed to identify the parties responsible (i.e., client, contractor, and consultant) for the most significant ERs as percentage values, in a manner where the total allocation of percentages for each risk summed up to 100%. Each and every response was analysed using equation 3 given below.

$$\boldsymbol{A^i} = \frac{\sum_{j=1}^{n} \boldsymbol{P_j^i}}{\boldsymbol{n}} \qquad \text{(Equation 3)}$$

Where; $\boldsymbol{A^i}$ – *Average Percentage of Risk allocation of* i^{th} *party,* $\boldsymbol{P}$ – *Rating (percentage) of each risks given by* j^{th} *respondent,* $\boldsymbol{n}$ – *Number of responses*

Phase II

In Phase II, the respondents were instructed to identify the five most appropriate risk response measures that could handle the most significant ERs associated with HCP. Mean Rating was used to calculate the significance level of each measure, as shown in equation (4)

$$\textbf{Mean Ratings} = \sum_{i=0}^{5} Xi \,/N \quad \text{(Equation 4)}$$

Where Xi - responses to specific rating point; N - number of responses,

3.4. Data Validation – Cronbach Alpha

Cronbach Alpha is a tool for validating data in a sample by determining the internal consistency of any test or scale and testing the reliability of responses before using them for a test or research (Amirrudin *et al.*, 2021). Consistency describes the interrelationship between the test items and the test scores, which range from 0 to 1. (Tavakol and Dennick, 2011). Cronbach alpha is used to determine the internal consistency for the assurance of effectiveness. In addition to that, the reliability estimate provides an idea of measurement error with related tests. The formula is as follows:

$$\propto = \frac{k}{k-1}\left(1 - \frac{\in Vi}{Vt}\right) \qquad \text{(Equation 5)}$$

Where, K = Number of risks, Vi = Sum of the Risks Variances, Vt = Variance of Total Scores in Risk Severity Index

As per Stephanic (2014), the Cronbach alpha thumb rule assesses the correctness and internal consistency of a data set, and if the value of Cronbach alpha is higher than 0.8, the data set is considered highly reliable.

3.5. Expert Profiles

This research required gathering data from specific contexts and groups of respondents relevant to the phenomenon in focus (Ames *et al.*, 2019). Therefore, the data collection had to be carried out in a purposeful way to gather the relevant data. Hence, the purposive sampling technique was used to choose the individuals who are best suited for this study in order to provide an informed view of the disputed subject of this study. Experts with more than ten years of expertise in the construction industry and more than five years of experience in HCPs were chosen, and emails and phone calls were used to contact them. Similarly, the questionnaire guidelines were sent out by hand or email.

According to Perera *et al.* (2014), the error rate of the Delphi method rapidly increases with the number of participants in the data collection until the participant number reaches 25. From there on, the error becomes constant. Accordingly, the sample of respondents for this research was limited to 52. Furthermore, this number is supported by the study of Badiu and Moran (2021), which states that 40 is a good participant number for most quantitative research, as shown by a computation that determines the bare minimum of users required to generate an accurate prediction of a population's behaviour based on a single study. For this study, particular emphasis was given to selecting environmental specialists who work as environmental consultants at contractor organisations to acquire their specialised knowledge and assure solid research findings. The profiles of the experts involved in the Delphi study are given in Table II below.

Insert Table 2

3.6. Colour Scales and Heatmaps

Colour scales and Heat maps are popular types of visualisations that use different colour tones to show two-dimensional tables of data (Gehlenborg and Wong, 2012). Heat maps are a good choice for the presentation of high-throughput data due to their dense and easy-to-understand layout (Knaflic 2015). In this study, two-dimensional scales (i.e., frequency of occurrence and level of impact) were used to determine the most significant ERs in HCP. Therefore, the colour scale and the heatmap method can be used to better visualise the components of risks and indicate their severity. The frequency of occurrence was primarily assessed using a scale of 1 to 5 based on how frequently it occurred on a yearly basis. Similarly, the level of the impact was ranked considering the percentage impact on Project Iron Triangle, which is based on time, money, and quality. The following scale demonstrates the colour codes for different risk scales, and the empirical data collected within this study was analysed accordingly.

Insert Figure 1

4. DATA ANALYSIS

4.1. Significant Environmental Risks in High Construction Projects

A total of 51 types of ERs were identified during the literature review shown in Table 1, and Delphi Round 1 was conducted to validate them. During this phase, 25 ERs were found to be valid for HCPs, and 23 were split, merged, and modified into 16 based on the experts' practical experience. Factors such as *"heritage conservation", "ecological road network theory,"* and *"ground movements"* were removed from the study since they achieved less than 80% agreement during Delphi round 1. Simultaneously, 11 new risks were identified, and a total of 52 ERs were advanced to Delphi Round 2.

During Delphi Round 2 Phase I, finalised 46 ERs were ranked based on severity index scores derived from probability and impact assessment. This study considered the ERs with severity indices of 10 or above as the most significant risks in HCPs (El-Sayeg *et al.*, 2018; Perera *et al.*, 2022). Table III illustrates the severity indices of the most significant ERs. The ERs that were newly discovered from the first round of the Delphi method are in *italics* in the below table. Similarly, the Cronbach alpha for this research was **0.9527,** which indicates the internal consistency of the sample is at an excellent level.

Insert Table III

"Natural resource depletion in Sri Lanka, like soil, sand, aggregate, etc., is found to be the most significant ER. It can cause further detrimental influences on projects in the form of material shortages, increasing material costs, soil and land degradation in nearby areas, time extensions, as well as cost claims and cash flow issues. *"Floods'* is a significant risk where it is reported with the highest significant impact level, but compared to the ten most significant risks, flooding involves the lowest frequency of occurrence. The elements that have been identified as the new risks and assessed as the most important ERs in the HCPS include *"disturbances to migration routes of animals, loss of bio diversity, loss of vegetation,* and *impacts on the natural drainage patterns and issues of irrigation water".*

4.2. Allocation of most significant Environmental Risks in Highway Construction Projects

Phase II of Delphi Round 2 identified the parties to whom the most significant ERs in HCPs can be allocated. Respondents were requested to validate the parties identified during the literature study and add new parties that they perceive as necessary. Based on the agreed-upon rate of 80%, only three parties were chosen as the parties responsible for the most significant ERs, and they were carried forward to Delphi Round 3.

The majority of the risks found have primarily been assigned to the Contractor, as indicated by the study findings. However, the ER "*Landscape change and fragmentation*" has been primarily assigned to the Client since landscape concerns are submitted to the design stage, and most of the tasks at the design stage are within the client's responsibilities. Despite the fact that the risks "*disturbances to migration routes of animals"* and *"loss of bio diversity"* were assigned to the contractor, the client has a large amount of responsibility for taking risks like these. Therefore, a significant number of risks have been allocated for the client's party as well, but as the consultant party works for the client party, it has only a smaller number of allocations of the most significant ERs derived from the empirical data.

4.3. Risk Response Measures to Manage the Most Significant Environmental Risks in Highway Construction Projects

The literature review discovered 24 risk response measures that were validated for the HCPs in Phase III of Delphi Round 2. During this phase, three (3) responses were merged, and 20 new risk measures were added. Simultaneously, seven (7) responses were discarded since they achieved less than 80% acceptance rate, and a total of 35 risk responses were forwarded to Delphi Round 3 for further consideration.

During Delphi round 3, respondents were asked to identify the five most appropriate risk response measures for each ER in HCPs by ranking them in the order of relevance from 5 to 1, with 5 being the most significant (Table IV). Furthermore, for each risk response measure, respondents were asked to choose a risk response strategy from risk transfer, risk avoidance, risk acceptance, or risk reduction. The risk response measures with Mean Rating values greater than 2.5 were deemed the most suitable (Choudhry and Iqbal, 2013; Iqbal *et al.*, 2015). The measures that were newly discovered from the second round of the Delphi method are in *italics* in the below table

Insert Table IV

Out of 24 risk response measures, 13 common risk response measures were identified to manage more than 1 most significant ER, and the rest of the 11 risk response measures were **unique** to managing a particular significant ER, as per the data analysis. Further, the majority of the risk response measures (17 out of 24) were derived as new response measures from Delphi Round 2, which has been indicated in *italics* in the above table.

The most commonly used risk response strategy or risk response measure selected by respondents considering the 11 most significant risks is "*strictly adhere to the environmental management plan".* Further, "*design the highway by considering environmental effects more than the cost effectiveness"*, and "make the *EIA (Environmental Impact Assessment) report approval process very strict by government authorities*" are other commonly used risk response measures selected by the respondents.

The most significant risks, such as "*loss of bio diversity"*, "*disruption to the physical environment"* and "*noise and vibration",* can be mainly controlled by common risk response measures with the use of very few unique responses. However, a risk like "*disturbances to migration routes of animals"* is very unique since it mainly requires unique risk response measures to handle it.

5. Discussion

5.1. Most Significant Environmental Risks in Highway Construction Projects

Several significant ERs were identified through the literature review, and some of those identified through the literature review were amended by the respondents during Delphi Round 1. At the same time, a few significant ERs were identified and added to the list as new risks by the questionnaire respondents during the Delphi rounds. "*Natural resource depletion in Sri Lanka, like soil, sand, aggregate, etc."* was found to be the first and most significant ER associated with HCPs, similar to general road construction projects as asserted by Coffin (2007). Sri Lanka is experiencing a worsening of this ER, and in particular, the building materials that are derived from natural resources are in significant jeopardy as a result of increased extraction rates. This issue is also posing a problem on a global scale. For example, 32–50 billion metric tons of sand and gravel are removed each year, and the rate of extraction far outpaces the rate of replenishment of natural sand (WWF, 2018). On the other hand, because of these increased extraction rates, disasters have become more severe, particularly *"landslides in mountain areas"* and "*Flooding",* which have threatened much of Sri Lanka's civilization over the past few decades. These can be supported further by the consequences of resource extraction, which result in *"Landscape Change and Fragmentation"* and river bed expansions. This ERs can be used for projects other than highway construction projects because natural extraction has an impact on all forms of construction, including general building projects (Alamgir *et al.,* 2017; Kishan *et al.*, 2014; Maria-Sanchez, 2004).

Further, "*improper solid waste disposal"* is a frequent significant ER in building and road construction projects (Maria-Sanchez, 2004; Walimuni *et al.*, 2017), and the findings of this study show that it is also a significant risk in HCPs as well. Increased urbanisation has resulted in a lack of waste segregation, inadequate garbage collection methods, and a lack of public commitment to waste management. This can be cited as a contributing factor to the aforementioned ER and is brought on by a lack of technical knowledge, a lack of waste management education and awareness, and a failure to implement the 3R principles (Dharmasiri, 2019).

Moreover, although "*adverse weather conditions, the introduction of chemical pollution,* and *air and water pollution* are significant ERs with a considerable influence on global well-being and biodiversity" (Abd El-Karim *et al.*, 2017; Chilshe and Yirenkyi-Fianko, 2012; Coffin, 2007; El-Sayegh and Mansour, 2015; Kishan *et al.*, 2014), the empirical findings have not identified them as the most significant ERs for HCP.

The Environmental Management Plan (EMP) plays a vital role in every construction project. Ansor *et al.* (2022) have identified a variety of risks that are subject to EMP and have shown how the risks addressed in EMP have an influence on construction projects. However, the most significant risks found in this study are not influenced by the risks addressed by EMP. Although a number of authors have stressed that "air, water, and ground water pollution" are the primary environmental concerns in general construction projects (Alfadil *et al.*, 2022; Banihashemi, 2021), the final outcome of this research is independent from them.

The most recent research by Azhagarsamy *et al.* (2021) has identified a number of risks connected to HCPs, including some of the main ERs. Weather implications, pollution, natural calamities, and the clearing of forests have been highly impacted by the bulk of HCPs. Although they were discovered in the literature review of this study, the results of the empirical data analysis do not advocate them as the most significant ERs in the Sri Lankan context.

5.2. The risk allocation party in Highway Construction Projects in Sri Lanka

Literature findings identified nine parties to whom risks could be assigned. During Phase II of Delphi Round 2, respondents agreed that when involved in HCP in Sri Lanka, three contractual parties—the client, contractor, and consultant—are responsible for the ERs. Furthermore, various research works, such as those by Hanna, Swanson, and Aoun (2014), Hiyassat *et al.* (2022), Tembo-Silungwe and Khatleli (2017), and Wang and Chou (2003), elaborated on how, in the construction industry, risk can be allocated primarily to the contractor and client. The research findings also confirmed the above statement by allocating the identified ERs for the contractor and client parties. However, the majority of the risks have been transferred to the contractor since contractors frequently possess a higher level of competence in environmental risk management than the client or project owner. They have dealt with issues like soil erosion, stormwater runoff, and habitat damage before, which are all significant environmental risks associated with construction activity. In addition, compared to the client, contractors have more control over construction-related operations. They are in charge of overseeing the daily operations of the construction site, which includes putting environmental safety precautions in place. The client can guarantee that the contractor takes a proactive approach to controlling environmental risks by assigning them to the contractor. At the same time, this study verified the consultant as the third party to whom risk can be allocated as per the empirical research findings.

5.3. Most appropriate Environmental Risks handling strategies/ response measures identified in Highway Construction Projects in Sri Lanka

There is a vacuum in adequate risk handling strategies and response measures in HCP in Sri Lanka when compared to risk response strategies and response measures found in the literature for construction projects in general. However, the findings of the study bridged this gap and provided new risk response measures based on the most significant ERs found during Phase III of Delphi Round 2 in this study. "*The contractors can transfer the financial losses occurred due to all risk events through insurance companies,"* is one of the major common measures that have been identified in this study and can also be used to mitigate the risks related to building construction and general road construction (Perera *et al.*, 2009; Yoon *et al.*, 2015). It is crucial to assign liability for these problems to insurance companies in HCPs since there is a chance for unforeseeable disasters like floods and landslides that cannot be avoided.

This study has concluded that the response measure "*if the current construction activities are affected, then the contractor can go for an alternative construction method to keep the construction schedule alive"* is a unique response measure towards minimising ERs in HCP. This is due to the fact that in situations like a pandemic, it is entirely the contractor's obligation to investigate alternate techniques with the client's and consultants' approval in order to preserve the construction schedule without adversely affecting the project's conclusion. Since the epidemic conditions can affect any other construction activity, Wang and Chou (2003) and Yoon *et al.* (2015) proposed this risk response as a risk measure for all types of construction projects.

A further point to be made is that there are some risk mitigation strategies that are the responsibility of both the client and the consultant. However, based on the outcomes shown in Table 3, it appears that the most environmental risks have been allocated to the contractor. In this case, the contractors think that these risks might be minimized by taking safeguards from the viewpoints of the clients and consultants; it may be desirable to jointly investigate viable solutions. Further, some authority over the projects is vested in the client and consultant as per the standard forms of contract. Therefore, contractors believe that some response measures need to be initiated by clients and consultants. The newly added response measures can be considered the most appropriate risk response strategies and measures to minimize the majority of key ERs in HCPs. The existing knowledge base on this area was extremely limited, and thus this study was able to shed light on it by discovering ERs and appropriate measures for them in HCP.

6. Conclusions and Recommendations

ERs related to HCPs have grown to be one of the most pressing issues in the modern construction sector since they can significantly impact the ability of contractors to complete the project and the whole eco-system in the world. This study identified the 11 most significant ERs in HCPs, addressing an existing research gap. Among the most significant risks, "*natural resource depletion in Sri Lanka, like soil, sand, aggregate, etc.,*", was identified as the most significant risk from the contractor's perspective. In managing ERs in HCPs, it is essential to implement the proper RM measures and strategies at the planning, design, and construction stages. Early preventative measures, such as "*strictly adhere to the environmental management plan; design the highway with environmental effects taking precedence over cost effectiveness; and make the EIA report approval process very strict by government authorities*," always lessen the effects of ERs and allow for the mitigation of potential future problems. The usage of the measures can be improved by implementing a point system, particularly for environmental issues, which encourages the contractors to earn high points by successfully and appropriately resolving environmental issues. Simultaneously, more attention should be paid to the environmental management plan, the use of recycled materials, the EIA report, and the monitoring system with government regulatory bodies.

There is a scarcity of literature on ER management in HCPs. Thus, this study contributes to both theory and practice by identifying significant ERs, risk handling strategies and measures, and risk allocation in HCPs. Furthermore, these findings can be used as a benchmark for further studies in other countries. In practice, the findings can guide the ongoing environmental and conservation efforts of construction parties, including NGOs funding such initiatives, and promote a sense of stewardship for the island's outstanding beauty and significance. The research benefits society by giving proper insight into ER management. Further Environmental pollution in HCPs is a severe issue in Sri Lankan and global contexts, both of which are critical issues for society. Henceforth, proper ER management by HCPs will ultimately benefit society drastically.

Though there may be some similarities between the international context and the Sri Lankan context, the applicability of the findings can differ from country to country and from region to region due to social, political, geographical, cultural, and technological differences in different countries.

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