DUAL MOBILITY NETWORKS: ASSESSING THE EFFECTIVENESS OF THE STRATEGIES TO MITIGATE ELEPHANT- TRAIN COLLISIONS IN SRI LANKA

WIJEKOON W.M.S.S.[1]* & DISSANAYAKE C.[2]
[1,2]University of Moratuwa, Katubedda, Sri Lanka
[1]wijekoonwmss.21@uom.lk, sameerawijekoon20@gmail.com, [2]clarenced@uom.lk

Abstract: Elephant-Train collisions constitute a major conservation threat in Sri Lanka, where railway infrastructure traverses traditional migratory routes of the elephants. This study assesses the effectiveness of current mitigation strategies using a mixed-methods approach, which includes field observations, interviews with railway officers, wildlife officers, police officers, and village people, and statistical analysis of historical collision records from the Department of Wildlife Conservation and Sri Lanka Railway Department. Two significant hotspots are selected for the study: Galgamuwa on the Northern line and Hinguraggoda on the Eastern corridor (Habarana- Galoya- Minneriya). The study found evidence of elephant injuries and deaths in both areas linked to seasonal resource availability and traditional movement routes. According to the site observations, the existing mitigation strategies can be categorized into two main groups: elephant-focused strategies, such as electric fencing, bio-fencing, and underpass tunnels; and train driver–focused strategies, such as clearing vegetation along the railway line and installing signboards to improve visibility. According to the data analysis, the clearing of vegetation has contributed to a reduction in elephant-related train accidents. The discussion emphasizes that elephant-train collisions are not random incidents but rather are the result of spatial disconnection, behavioral adjustment, and infrastructure management that have developed over time.

Keywords: *Elephant-Train Collisions, Underpass, Mitigation Strategies, Electric Fences, Traditional Methods*

1. Introduction

Human-elephant conflict (HEC) is a critical issue and socio-economic challenge affecting many Asian and African countries. As global elephant populations face habitat fragmentation, increasing human encroachment into traditional elephant ranges has increased interactions. Among the 13 Asian elephant range states, Sri Lanka is considered a key location due to its disproportionately high elephant density and one of the highest levels of HEC relative to its size and human population density (Fernando & Pastorini, 2011).

Sri Lanka is a tropical island situated between latitudes 5° 55' and 9° 51' N and longitudes 79° 41' and 81° 54' E in the Indian Ocean. Covering an area of 65,610 square kilometers with a 1,700 km long coastline, the island features mountainous terrain in the south and central regions, while its north is predominantly flat (Koralagama, 2008). Despite its modest size, Sri Lanka supports approximately 10–20% of the global Asian elephant (*Elephas maximus*) population, although it comprises only 1–2% of their global range (Fernando et al., 2011). The subspecies found here, *Elephas maximus*, is listed as endangered on the IUCN Red List (Choudhury et al., 2008). It is not only a symbol of national heritage and culture but also plays a vital role in maintaining the island's ecological balance. Historically, elephants have held a revered position in Sri Lankan culture and tradition. They were not only symbols of royal power and religious significance but were also employed in warfare, construction, and ceremonial processions (Jayawardena, 2006; Suckling, 1876). Ancient records suggest that Sri Lanka exported elephants to countries such as India, Myanmar, China, Egypt, and Persia, a testament to their importance even beyond the island (Tennent, 1860).

However, this long-standing human-elephant relationship has deteriorated dramatically in the face of rapid development and deforestation. Urban expansion, commercial agriculture, and infrastructure projects have led to severe habitat fragmentation, resulting in frequent and often fatal encounters between elephants and humans. Among the various forms of human-elephant conflict in Sri Lanka, elephant-train collisions represent a distinctive and escalating threat. While traditional HEC, such as crop raiding or village intrusions, tend to result in local damage, train collisions cause sudden, often fatal injuries to elephants, sometimes involving entire herds. Unlike in India or Thailand, where such accidents are often spread across vast networks, Sri Lanka's compact geography and dense railway lines intersect directly with key elephant habitats, particularly in regions like the Eastern and North-Central provinces.

According to the 2011 elephant census, Sri Lanka was home to 5,879 wild elephants, with significant populations found in the Mahaweli, eastern, and northwestern regions. The same census revealed that over 67% of elephants reside in wildlife reserves, with nearly 30% in forest reserves and the remainder in unprotected landscapes, many of which are bisected by railway lines. Notably, 17 out of the 25 districts in Sri Lanka report active elephant populations, with 107 divisional

*Corresponding author: Tel: +94 740462080 Email Address: wijekoonwmss.21@uom.lk, sameerawijekoon20@gmail.com
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secretariats identified as HEC hotspots. Between 2011 and 2015 alone, 333 human lives and 1,147 elephants were lost due to HEC (DNP, 2016). highlighting the critical need for sustainable mitigation strategies. While fences, trenches, and electric deterrents have been used to address general HEC, elephant-train collisions remain inadequately addressed and often absent from broader conservation dialogues. These incidents not only endanger wildlife but also pose safety risks and economic burdens to the railway system and nearby communities.

2. Research Need

The growing number of collisions with railway infrastructure is causing an unprecedented crisis for Sri Lanka's elephant population. Alarming trends in elephant mortality rates are shown by recent statistics, with deaths from railways accounting for a large portion of the overall decline in elephant populations. These incidents have become increasingly frequent and severe, necessitating the development of quick and efficient intervention plans. Existing mitigation strategies in Sri Lanka have shown limited success in providing comprehensive solutions to elephant-train conflicts. While various approaches have been implemented, including schedule modifications, warning systems, and physical barriers, the lack of integrated landscape architectural solutions represents a significant gap in current conservation and transportation planning approaches.

3. Literature review

Elephants are the largest living land animals. Identical features include a long trunk, Tusks, large ear flaps, pillar-like legs, and tough but sensitive grey skin. The trunk is prehensile, bringing food and water to the mouth and grasping objects. Tusks, which are derived from the incisor teeth, serve both as weapons and as tools for moving objects and digging. The large ear flaps assist in maintaining a constant body temperature as well as in communication. Evolution of the elephants, African and Asian elephants are the two major species with morphological differences and similarities. Elephants are distributed in 50 countries in the world, 13 Asian countries, and 37 African countries. There are global population of Asian elephants is around 40,000 (Pastorini, 2011). The 13 Asian countries: Sri Lanka, India, Nepal. Bhutan, Bangladesh, Myanmar, Thailand, Laos, Cambodia, Vietnam, Malaysia, Indonesia, and China. (Fernando & Pastorini, 2011), IUCN red listing criteria have listed elephants are an “Endangered species” due to the threats.

Elephants are crucial to their ecosystems, acting as both ‘keystone species’ and ‘ecosystem engineers’. They play a vital role in maintaining biodiversity, shaping and influencing plant and animal communities. “Elephants, with an adult weight of 1,000-5,000kg, are the biggest terrestrial animals” (Fernando P.,2015). When direct observation can be seen, solitary elephants and herds of elephants are seen according to age and sex. A herd consists of adult and young female elephants and offspring. Male offspring drift away from the herd when aged. When a herd usually experiences human aggression, the adult males from that group are more likely to develop into highly aggressive individuals, also known as ‘Problem elephants.’ (Fernando. P,2015)

3.1. ELEPHANT – TRAIN COLLISIONS: WHY DOES IT HAPPEN?

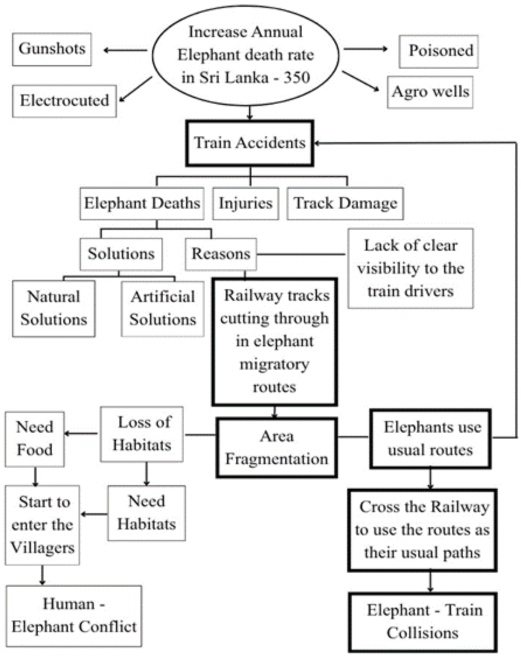

Figure 1: Reasons for elephant death (Source: Compiled by Author)

Elephant – Train Collisions have become a critical issue, resulting in elephant mortality. It concerns several Asian and African countries where expanding the railway infrastructure intersects with traditional elephant habitats. This phenomenon occurs across elephant habitats Worldwide and shows the complex relationship between the conservation of the Elephant population. In the global context, face these critical issues about elephant-train collisions. "India is one of the countries with serious problems of train-wildlife collisions. This is because the Indian Railways is one of the World's largest railway networks" (Mukti Roy and Raman Sukumar,2017).

The transportation infrastructure development has fragmented traditional migration routes and feeding areas. "Since 1978, the country has lost 150 elephants due to train hits. These include 36% cases recorded from Assam, 26% in West Bengal, 14% in Uttarakhand, 10% in Jharkhand, 6% in Tamil Nadu, 3% in Uttar Pradesh, 3% in Kerala, and 2% in Odisha" (Roy *et al.*2009; Rangarajan *et al.*2010). Most of the Railway lines create linear barriers that force elephants to cross tracks regularly, moving between the habitat patches. Especially in South Asia, railways often cut through the dense forests, and some are in the protected areas, fragmenting habitats. Railway lines developed, cutting through the ecological zones. Due to this problem. It affects the elephant movements as barriers. So, the impact of the area fragmentation can loss of habitats of the elephants. Without corridors to link each habitat, herds can have trouble reaching food and water at certain times of the year, according to the seasonal changes

3.2. MITIGATION STRATEGIES USED IN GLOBAL CONTEXT
A variety of methods have been created and used worldwide to combat elephant-train collisions, both based on traditional methods and new inventions. Nations such as India and Kenya, as well as other countries in Africa, have introduced approaches to alleviate elephant mortality while creating a sustainable approach. However, many of the methods were also expensive and vulnerable in terms of weather, which ultimately limited some of their sustainability. (Ettager. H, 2017), Electric fencing is not only sustainable but also effective, as it reduces the need for ongoing human presence while providing a consistent barrier to intrusions.

In contrast, methods such as beehive fences are effective, but rather temporary, or reliant on number of hives and ensuring hives are populated readily, while also providing socio-economic benefit through honey production for the local people.

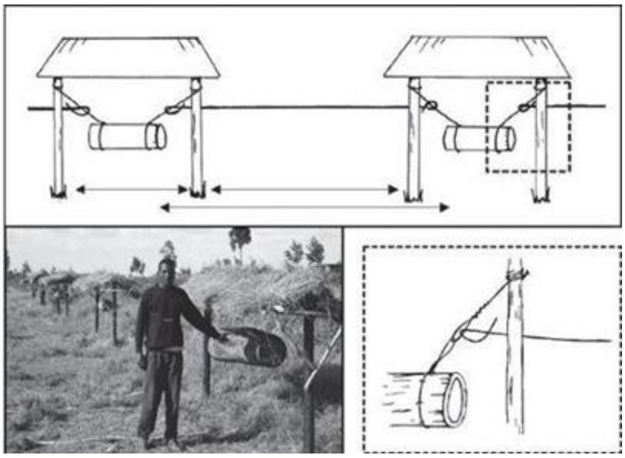

Figure 2: Beehive fencing system (Source: *Human-Elephant conflict mitigation methods)*

Large infrastructure/underpass projects, such as Amboseli National Park in Kenya, have been developed. These projects allow an elephant to cross transport corridors irreversibly while still providing connectivity throughout the landscape. These examples illustrated the broadness of mitigation methods for elephant train collisions, ranging from inexpensive community-driven methods to infrastructure-based solutions. Longer underpasses may require wider and higher dimensions to maintain similar openness as shorter underpasses.

Table 1: Standard underpass dimensions

Underpass length across LTI (m)	Minimum underpass dimensions		
	Width (m)	Height (m)	Openness index
≤10	12.0	6.0	7.2
11-20	15.0	6.5	4.9 – 8.9
>20	20.0	7.0	4.7 – 6.7

4. Methodology

This part contains the methodology used to assess the effectiveness of strategies to mitigate elephant–train collisions in Sri Lanka, mainly focusing on case study areas such as Galgamuwa, Habarana-Galoya-Minneriya to Hinguraggoda railway route. The research was conducted with a mixed-methods approach, combining both primary and secondary data collection techniques.

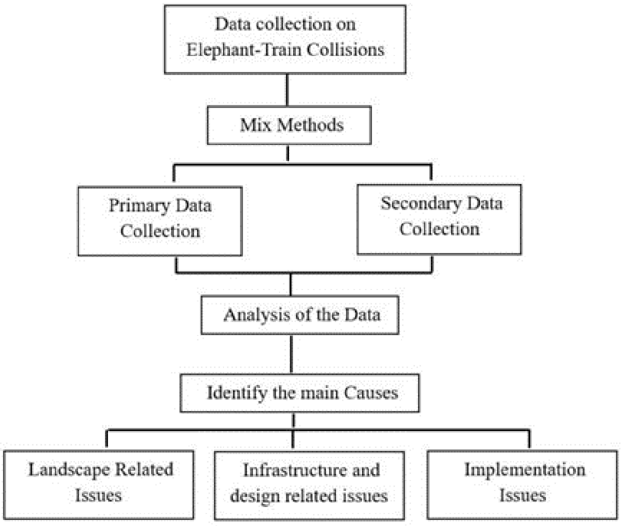

Figure 3: Methodology *(Source: Compiled by author)*

4.1. PRIMARY DATA COLLECTION METHODS

4.1.1. Site Observations and Field Surveys

In the field visit, direct observations were conducted along the selected railway routes to document elephant migratory patterns, high Elephant-Train collision hotspots, Land use activities in the surrounding and existing mitigation strategies, implemented structures. The research has documented spatial characteristics by utilizing photography. Field notes were collected to identification of physical features which may have an impact on elephant movement, such as water ponds, paddy fields, and vegetation corridors.

4.1.2. Interviews

Semi-structured interviews were conducted with Railway officers, Wildlife Conservation officers, Local police officers, and Village people to provide multiple perspectives about the Elephant-Train Collision situation and the mitigation efforts. The multi-stakeholder approach helped to identify the different data about the Elephant-Train Collisions (ETC) from different perspectives under different experiences.

Mainly, the interviews were organized around three key roles;

- Past and current incidents of Elephant- Train Collisions (Including frequency, location, and the situation of the surroundings)
- Perceptions of existing mitigation strategies (Including the effectiveness, Implementation challenges)
- Community experiences/ Management strategies (Including how populations adapt to and manage the upcoming challenges according to the elephants' movements across railway corridors)

4.2. SECONDARY DATA COLLECTION METHODS

4.2.1. Literature Survey

A comprehensive literature review was conducted to identify the global and local context of Elephant-Train Collisions. The review done by examined government reports, conservation publications, and documented case studies from different countries with a significant railway network and the elephant populations and the elephant death rate. The literature review identified best practices taken from the global context to mitigate the collisions, including early warning systems, habitat corridor restoration, and community-based engagement.

4.2.2. Past Statistical Records

Collision data and the historical records were collected from the different institutional sources to identify a comprehensive understanding of the Elephant-Train interactions of the specific locations.

- Department of Wildlife Conservation (DWC) – Elephant habitat areas/Detailed records of the Elephant population and the mortality rates
- Sri Lankan Railway Department – Detailed record of elephant deaths due to Train collisions/ Specific locations where accidents happened
- Sri Lanka Police (Police stations of the selected case studies)

5. Case study and data analysis

5.1. CASE STUDY SELECTION CRITERIA: GALGAMUWA, HINGURAGGODA

The case study areas for this research were selected based on their significance as critical elephant-train collision hotspots in Sri Lanka's railway network. The Northern Line section at Galgamuwa was selected with urgency due to its frequently high rate of ETCs, where elephants repeatedly cross rail tracks while moving between Wilpattu forest patches, irrigation tanks, and agricultural lands. This site consistently represents one of the highest mortality zones over recent years for elephants involved in train collisions, suggesting that targeted mitigation measures are needed with urgency.

The Eastern and Northern railway corridors from Habarana-Gal Oya-Minneriya to Hinguraggoda were selected because of their ecological context. This stretch of rail line physically transects elephant habitat and migratory corridors, particularly near Minneriya National Park, where elephants move seasonally during the "Gathering" period, increasing the likelihood of elephant–train encounters. The Hinguraggoda extension represents a different landscape, a transitional landscape of forests, tanks, and villages, where the human-elephant coexistence is complex.

5.2. CASE STUDY 01: GALGAMUWA

Galgamuwa is a region in the Kurunegala District, located in Sri Lanka's North/ Western North Central Dry Zone interface. It is located on the Northern railway line, which links parts of the Wilpattu forest ecosystem to agricultural and forest patches surrounding it. The Landscape is mostly flat with paddy fields, chena (slash-and-burn) cultivation, and forest remnants scattered among human settlements. There are several seasonal and permanent tanks and irrigation channels, which attract wildlife.

Figure 4: Galgamuwa implemented strategies layout *(Source: Compiled by author)*

The Galgamuwa area of the Northern railway line is identified as one of the critical Elephant-Train Collision hotspots in Sri Lanka. The existing mitigation strategies that are used in Galgamuwa can be mainly divided into two sections:

A. Elephant focusing strategies
B. Train drivers' focusing strategies

A. Elephant focusing strategies

The elephant focusing strategies used in Galgamuwa to mitigate collisions include maintaining the natural barriers, combining with an electrical fencing system to use for the edge of the transport route, implementing an underpass tunnel to discourage elephant crossings, and decreasing the elephant-train interaction between the transportation routes.

A.1 Using natural Barriers (Bio-fence)

As a natural barrier, used to plant thickly-planted Agave species. The type of sharp, spiky leaves, dense plants make it difficult for elephants to cross the track. This barrier serves as a sustainable, low-maintenance strategy. The method is relatively cost-effective, eco-friendly, and combines with the local ecosystem.

Figure 5: Using natural barriers for the edge of the road (Bio-fencing system)

A.2 Underpass tunnel

In Galgamuwa, the underpass tunnel has been recognized as an artificial intervention to allow elephants to cross the rail lines. Existing tunnel, which are old irrigation and drainage tunnel. These tunnels will be designated as crossings, meaning elephants can cross the railway lines at these locations, which will mitigate the risk of accidents. The planned underpass tunnel will be positioned at area commonly used by elephants to cross. The proposed tunnels will include guiding barriers to help direct elephants. The existing and proposed tunnels are designed to complement each other to create a balance between ecological connectivity and railway safety.

Figure 6: Existing underpass tunnel

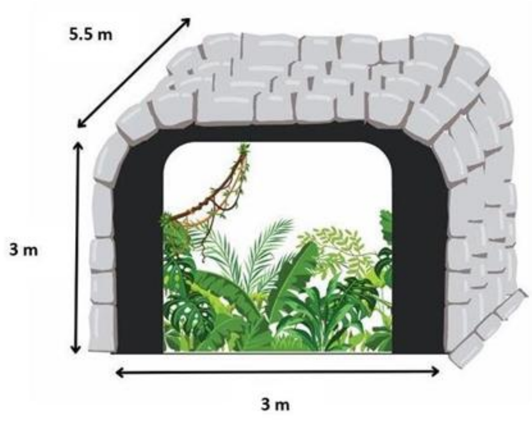

Figure 7: Measurements of the existing underpass tunnel

B. Train driver focusing strategies

In Galgamuwa, some other mitigation strategies mainly focus on the train drivers to reduce elephant-train interactions, including clearing vegetation up to 20meters on both sides of the railway main tracks and CCTV lighting systems that offer live monitoring and advanced warnings. These technical solutions improve clear visibility and safety when controlling human-elephant interactions along railways.

B.1 Clearing from the edge of the railway line

In Galgamuwa, the vegetation alongside the railway line is cleared back at least 20 meters on either side to improve visibility to train drivers. This will be used as a natural method of safety to see elephants that are approaching or crossing the tracks. With these areas having dense shrub and tall grass, visibility is decreased both for drivers to see the elephants before they hit them as well as for the elephants being able to be approached at the tracks. While allowing elephants to be protected both by a natural boundary and fencing, they are frequently safer from elephant-train collisions in a way that preserves a natural environment.

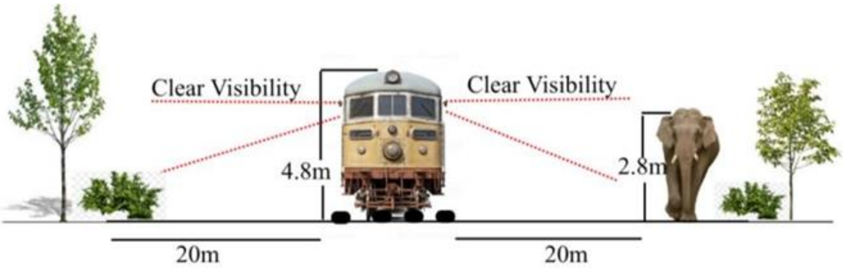

Figure 8: Clearing vegetation to improve visibility

B.2 CCTV lighting system

In Galgamuwa, the CCTV lighting system is introduced as a modern strategy to monitor and reduce elephant-train collisions as a lighting system. A CCTV camera is installed along railway tracks, enabling real-time detection of elephant movement near critical zones. Integrated lighting systems illuminate the area during nighttime, improving visibility for both train drivers and the monitoring team. The CCTV system strengthens safety by combining technology with traditional mitigation methods.

Figure 9: CCTV lighting system in Galgamuwa

5.3. CASE STUDY 02: HINGURAGGODA

Hinguraggoda is situated in the Polonnaruwa District of Sri Lanka's North Central Province, located in the country's Dry Zone. It is located around 60 km north of Polonnaruwa town and 220 km north east of Colombo city, and situated between the Mahaweli River basin and the Minneriya–Kaudulla tank system, forming part of the historic irrigation landscape of the area. The elevation of Hinguraggoda is roughly 60– 90 meters above sea level with flat to slightly undulating land primarily consisting of paddy fields, village tanks and chena (shifting cultivation) lands.

The Habarana-Galoya-Minneriya to Hinguraggoda railway corridor has become a hotspot for elephant-train collisions resulting in high wildlife mortality rates and disrupted rail services. To combat this serious issue, authorities have instigated a series of mitigation measures aimed at conserving elephant and train operations.

A. Elephant focusing strategies
B. Train drivers' focusing strategies

A. Elephant focusing strategies

In the Habarana-Galoya-Minneriya to Hinguraggoda railway route mostly used electric fence as an elephant focusing strategy to mitigate train collisions.

A.1 Using natural Barriers (Bio-fence)

Along the railway route, a continuous mitigation strategy has been identified through the use of an electric fencing system to reduce elephant access.

Figure 10: Electric fencing system near the railway line

B. Train driver focusing strategies

B.1 Clearing from the edge of the railway line

Clearing vegetation along the railway edges across the Habarana- Galoya- Minneriya to Hinguraggoda corridor was employed as an effective way to facilitate train driver visibility to find elephants on or near the railway corridor. Once vegetation was cleared, train drivers were able to see concealed elephants approaching the track before they got too close.

Figure 11: Clearing from the edge of the railway line

5.4. DATA ANALYSIS

The Selection of Galgamuwa and Hinguraggoda as primary case study locations was strategically determined based on their documented high rate of elephant deaths due to train accidents

Figure 12 shows the number of elephants killed as a result of train accidents in Galgamuwa in thirteen years (2011–2023), totaling 19 deaths over the years, with great variability from year to year.

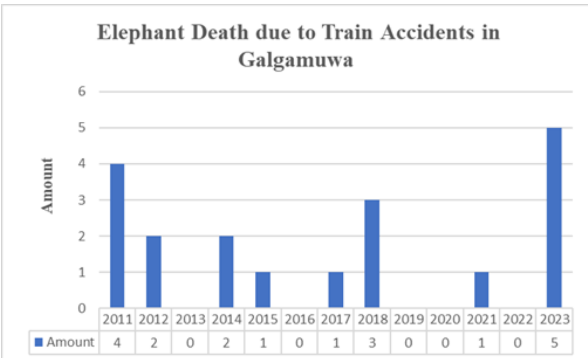

Figure 12: Elephant death due to train accidents in Galgamuwa *(Source: Compiled by author)*

The data indicates that the highest number of five deaths occurred in 2023, representing 26.3% of all fatalities recorded during the study period. This makes 2023 the year with the highest number of elephant deaths caused by trains within the study area. The second highest number of deaths, four (21.1% total), was in 2011, followed by three deaths (15.8%) in 2018. The three years combined accounted for 63.2% of deaths recorded overall. Other years that had a moderate impact included 2012 and 2014, with two deaths each (10.5% each). Years with lower impact included 2015, 2017, and 2021, which showed only one death each (5.3% each), which combined total 15.9%. Additionally, five years during the study (2013, 2016, 2019, 2020, 2022) had no deaths recorded, which was 38.5% of the years observed with no death included. The data shows a pattern of worrying resurgence, where there are periods of quiet with no deaths or one death, followed by periods of a sudden increase in deaths. For instance, there was a high increase in the total number of deaths from zero in 2022 to five in 2023, which showed a dangerous escalation in a critical situation. The 2023 mortality rate was 25.0% higher than the initial year's (2011) mortality rate. So, even after more than a decade of likely potential mitigation, elephant deaths from train fatalities are still continue at very high proportions.

Figure 13 shows the number of elephants killed as a result of train accidents in Hinguraggoda over the eight-year period from 2018 to 2025, which shows a total of 29 deaths and some substantial fluctuations between years.

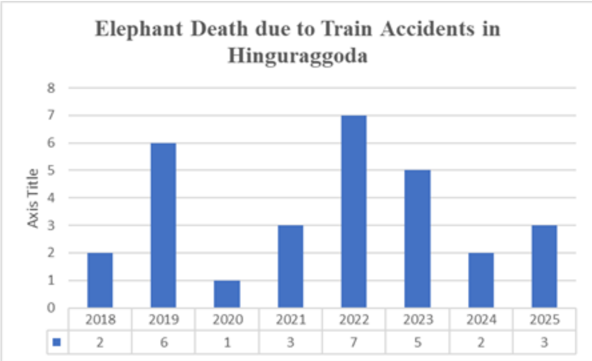

Figure 13: Death due to train accidents in Hinguraggoda *(Source: Compiled by author)*

The data indicates that the year of 2022 suffered the most casualties of elephants due to this condition, with 7 deaths across the year (which is 24.1% of all train-related elephant deaths within the study). The second highest number of deaths was in 2019, with 6 deaths (20.7% of the total), and 2023 exhibited the third most deaths, with 5 (17.2% of total). In fact, this streak of high-escalation years (20192022-2023) accounts for 62% of all elephant vs. train conflicts since 2018.

Moderately impacted years for elephants through train-related incidents included 2021 and 2025, where 3 deaths (10.3% each) were counted, and years with lower casualty counts (2 each) were 2018 and 2024, with a total representation of 13.8% of total deaths. One lower impact year stood out was 2020, with only 1 elephant killed (3.4% of total). 2020 is recognized as the lowest state for the 8 years documented. The data shows a concerning spike from 2021-2022, where fatalities more than doubled from 3 to 7 death, or a 133% increase, which strongly suggests a critical build-up of risk for elephants and trains during this time. While deaths decreased post-2019 to 5 in 2023 and to only 2 in 2024, the increase to 3 deaths in 2025 indicates persistent risk factors. In comparing the beginning and end of the study period, the number of deaths in 2025 (3) was greater than in 2018 (2) by 50%, suggesting that while mitigation efforts may have occurred in the past seven years, the issue has not been fully resolved. The peaks in 2019 and 2022 with a relatively quiet 2020 in between indicates that elephant-train collisions occurring in Hinguraggoda may be driven by cyclical influences, including seasonal migration patterns for the elephants, changes to the frequency or speed of trains, and/or changes to agricultural cycles that drew elephants to railway lines, or inconsistency in the implementation of wildlife protection measures along certain critical railway corridors.

Figure 14 shows the yearly counts of elephant deaths due to train accidents in Galgamuwa and Hinguraggoda from the years 2018 to 2025. There are clear differences in the two data sets.

There were occasional deaths in Galgamuwa, with significant spikes in 2023 and 2024, but many years without a death or low counts. Upon examining the data from Hinguraggoda, there is a clear increase starting in 2018, with a high peak in 2019 and again in 2022, with proportionally higher counts in the previous year's suggesting the numbers will trend higher. The contrast shows a greater cumulative and severity increase in Hinguraggoda in a shorter time, while Galgamuwa has relatively few instances of deaths that are more sporadic and over longer periods of time. This indicates different implications for elephant conservation in both areas.

In 2018, a natural trenching system was implemented in sections along the railway corridor within the Galgamuwa area as an initial mitigation effort to reduce the deaths of elephant-train collisions. The accident amount between 2019 and 2022 varied year to year. In 2021, an electric fencing system was implemented in both the Galgamuwa and Hinguraggoda areas.

In 2022, a bio-fencing system was established in the Galgamuwa area, in combination with the existing electric fencing system. During the years 2022 to 2024, the accident amount remained relatively high compared to all other years, showing that the bio-fencing system alone was not sufficient to completely mitigate elephant-train collisions. An underpass tunnel system is proposed in Galgamuwa for the maintenance of the railway track in 2024. In 2023, warning signboards were an intervention installed in known hotspot areas in Hinguraggoda, and in 2024, clear vegetation along the proposed rails to increase visibility along the railway. After 2024, there was a noticeable decrease occurrence of elephant-train collisions in Galgamuwa. However, the rate of elephant-train collisions in Hinguraggoda remained continuous.

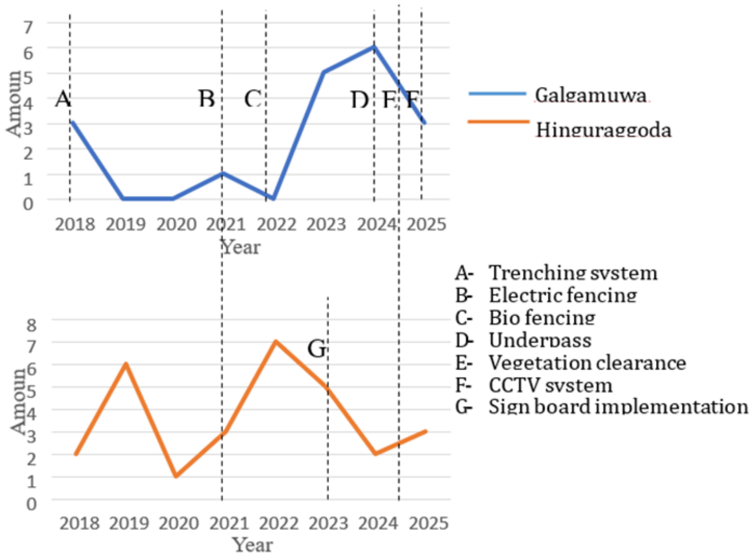

Figure 14: Comparison of accidents *(Source: Compiled by author)*

6. Discussion

This study compares two cases: Galgamuwa and along the Habarana-Galoya-Minneriya to Hinguraggoda railway corridor in comparison of the existing literature and understanding the causes of elephant-train collisions and the effectiveness of current strategies. According to the collected data the existing implemented strategies in Galgamuwa and Hinguraggoda are divided into two main categories as (A) elephant-focusing strategies and (B) train driver-focusing strategies. Mainly elephant focusing strategies are implemented to control elephant movement or to disrupt elephant movement patterns. And the train driver focusing strategies is that the train driver always takes the train with complete awareness when the train driver is moving through places where the elephant migratory spots. That whole situation depends on the train driver.

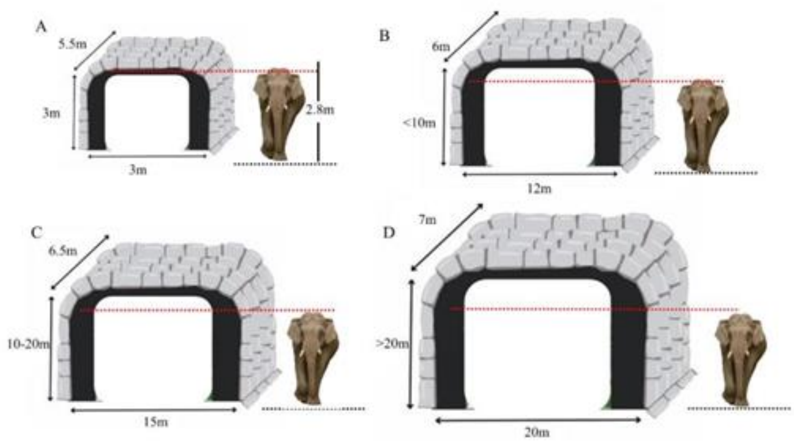

Figure 15: Comparison the measurements of Galgamuwa underpass with standard measurements

According to the above image, the Galgamuwa underpass cannot be used by elephants due to this measurements failure. According to the standard size, it should be at least 6m in length, 12m in width and 10m in height. But according to the Galgamuwa underpass the length is 5.5m, width 3m and height is 3m. As the result the underpass is proved to be ineffective due to measurements failure and non-usage. There is a possible point that used technical methods with the landscape solutions. Sensor-based warning systems, CCTV systems and alarm systems have been piloted along railway corridors in India with noticeable success (Kumar et al.,2020). In general, the discussion emphasizes that elephant-train collisions are not random incidents but rather are the result of spatial disconnection, behavioral adjustment and infrastructure management that have developed over time. Vegetation clearance was implemented in 2024 in both Galgamuwa and Hinguraggoda. Galgamuwa has shown a decrease in elephant deaths after 2024 and this may be use of CCTV system at the same time. Moreover, Hinguraggoda has been a changes in elephant deaths since signboards were implemented since 2023. Clearing vegetation improves the clear visibility to the train drivers. The findings of the study make a case for railway corridors not simply as transport infrastructure but as multi-functional ecological infrastructures for biodiversity, connectivity, and safety.

7. Conclusion

The study examines the spatial, ecological and design aspects if ETC across the Galgamuwa and Hinguraggoda in Sri Lanka. According to the analysis majority of collisions happened during dry seasons. Elephants are forced to traverse human transport routes due to the finding resources. Although strategies such as bio-fencing, electric fencing, sign boards, and vegetation clearing have been used, there have been wide variations in effectiveness. Furthermore, studies I suggest the future recommendations as implementing long-term monitoring system to collect more validity data from using technical methods. So, I recommend ensuring the consistency of bio fencing method along the identified risk spots. And the main point that was identified as ensuring the methods that can improve clear visibility for the train drivers to be more aware.

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