SRI LANKA'S TRAIN-ELEPHANT COLLISION CRISIS: A REVIEW OF POLICY AND TECHNOLOGICAL INTERVENTIONS

TGD Kalhara[1] and K Fernando[2]

Abstract

Human-elephant conflict (HEC) is a long-standing issue in Sri Lanka, where expanding human settlements, agriculture, and infrastructure have increasingly encroached upon elephant habitats. This conflict has intensified in recent years, resulting in significant casualties on both sides, including damage to crops, property, and lives. However, increasing human expansion and infrastructure development have led to frequent human-elephant conflicts (HEC). Sri Lanka's railway infrastructure intersects with critical elephant habitats, creating a dangerous overlap that has resulted in increasing train-elephant collisions, particularly from 2020 to 2025. These incidents pose a severe threat to the country's biodiversity, especially its endangered elephant population, while also causing infrastructure damage and operational disruptions. This study explores the root causes, statistical trends, policy actions, and technological interventions aimed at reducing train-elephant collisions across high-risk railway corridors such as the Trincomalee, Batticaloa, and Northern lines. This study reviews the causes, statistical trends, government policies, and technological innovations aimed at addressing the issue. While policy interventions such as train speed limits, schedule adjustments, and vegetation clearance have been implemented, their effectiveness has been limited by enforcement challenges and infrastructural constraints. Meanwhile, promising technological solutions such as AI-powered detection systems, Arduino-based sensors, Fiber Bragg Grating (FBG) sensing technology, and high-frequency sound deterrents have shown potential in detecting elephant movement and issuing early warnings to prevent collisions. Moving forward, it is essential for policymakers, conservationists, and technologists to work together in designing sustainable solutions that protect both Sri Lanka's national heritage the elephant and the safety of its railway system. Only through integrated and innovative approaches can a balance be struck between development and wildlife conservation.

Keywords: Artificial Intelligence, Conservation, Elephant Collisions, Railway Safety, Wildlife Protection

[1]Faculty of Computing and Technology, University of Kelaniya, Sri Lanka.

Email: kalhara-et21048@stu.kln.ac.lk https://orcid.org/0009-0001-2948-960X

[2]Faculty of Computing and Technology, University of Kelaniya, Sri Lanka.

Email: kasunf@kln.ac.lk https://orcid.org/0000-0001-8366-6219

Received date: 28.05.2025 Accepted date: 05.07.2025
Print Publishing Date: 31.10.2025 Web Publishing Date:31.10.2025

Introduction

Sri Lanka is home to significant of Asian elephants (*Elephas maximus maximus*) about 7500, a species that plays a vital role in maintaining the country's ecological balance. However, increasing human expansion and infrastructure development have led to frequent human-elephant conflicts (HEC). It reveals that while human and elephant mortalities were similar in 1991, subsequently, there has been a noticeable escalation in violence against elephants over time. Also, the elephant and human mortalities are increased approximately by 900% and 200% respectively, indicating the seriousness and importance of mitigating HEC. Traditional elephant migratory routes increasingly overlap with railway tracks, especially in the North Central, Eastern, and Northern provinces. This overlap significantly heightens the risk of collisions, with elephants crossing railway lines in search of food, water, or during seasonal migrations (Gunawansa et al., 2023).

Among these, train-elephant collisions have become a major conservation concern, resulting in substantial elephant fatalities and economic losses. Between 2020 and 2025, numerous incidents have been reported along key railway routes, particularly in regions where railway lines intersect traditional elephant migration corridors. The primary causes of these accidents include habitat fragmentation, lack of railway safety measures, and limited awareness among train operators and local communities. In response, Sri Lanka has introduced several policy interventions and technological solutions aimed at reducing train-elephant collisions. Elephants are often more active at night. Poor visibility, combined with the absence of adequate lighting or warning systems, makes detecting elephants difficult for train operators (Kioko et al., 2008).

Elephant-train collisions in Sri Lanka have become a critical issue, threatening the survival of the country's endangered elephant population and causing significant damage to railway infrastructure. The expansion of railway lines, particularly in elephant corridors and protected areas, has increased the frequency of these accidents. Despite conservation efforts, the number of train-elephant collisions has risen over the years, with many incidents resulting in the death of multiple elephants at once.

Methodology

This study utilized a qualitative desk research approach, reviewing literature from 2020–2025 using databases such as ResearchGate, Google Scholar, and SpringerLink. Keywords such as "elephant-train collisions," "AI in wildlife conservation," "Sri Lanka HEC," and "railway mitigation technologies" were used. Articles were selected based on relevance to Sri Lanka or offering comparable global interventions. Data were analyzed thematically to identify trends in policy responses, technological innovations, and ecological outcomes.

Literature Review

The human-elephant conflict is a major issue in environmental and economic Sri Lanka. As human populations expand, elephants lose their natural habitats due to deformation, agricultural expansion, infrastructure development, train- elephant collisions are leading to frequent encounters between elephants and humans. The result of human-elephant conflict (HEC) (Köpke et al., 2023)significant losses, including deaths of human and elephants, economical damage and to ecological balance. The roots of the HEC in Sri Lanka date back centuries. Elephants have traditionally roamed across large territories, and with the expansion of agriculture, plantations, and settlements during the colonial and post-colonial periods, their natural habitats became increasingly fragmented. Rapid land-use changes, especially in the dry zone areas where elephants are most prevalent, intensified competition for resources between humans and elephants. Crops like paddy, banana, and sugarcane, which are cultivated extensively in these regions, are highly attractive to elephants, resulting in frequent crop raiding.

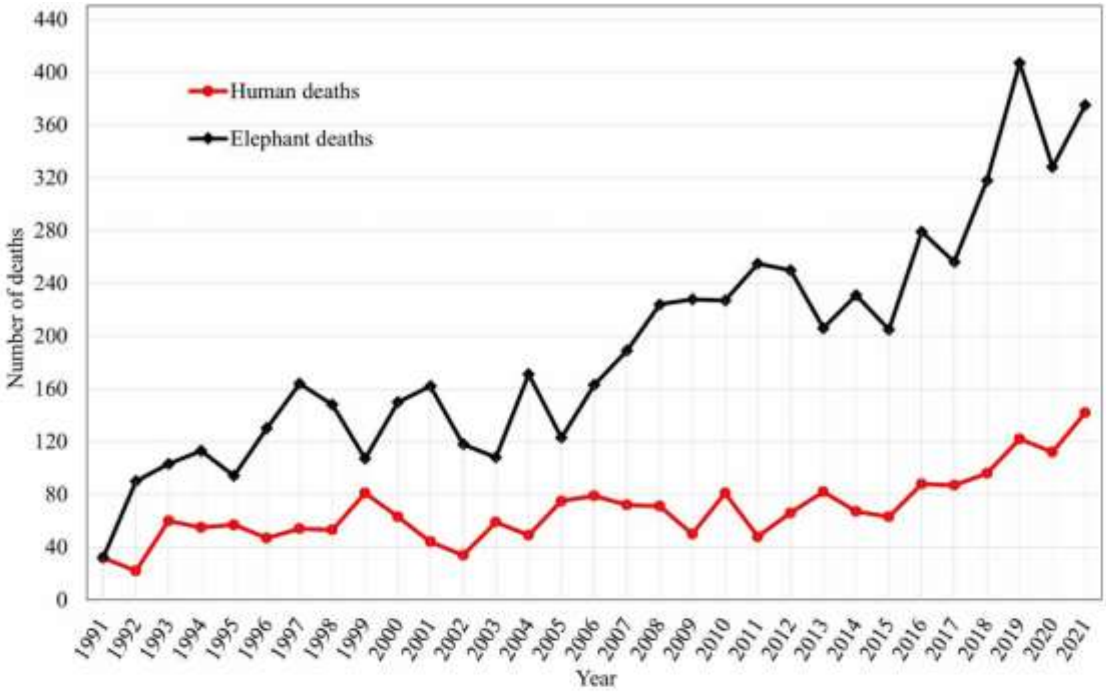

Figure 01: Human and Elephant Deaths in Sri Lanka (1991–2021)

According to sources of (Gunawansa et al., 2023) between 2020 to 2025 annually 400 deaths of elephant and 100 human deaths reported Fig.1 from human-elephant conflict. Among them, elephant deaths are mainly reported in train- elephant collisions in 2020 to 2025 years. Train-elephant collisions are a major concern, Fig.2 especially along the Trincomalee, Batticaloa, and Northern railway lines, where habitat fragmentation and seasonal elephant migration increase accident risks. The reasons for these accidents, limited hearing range for high frequency sounds, limited visual range at night time, sensory distractions and late response and limited interaction with train. All accidents are happened in areas where there are dense trees or low visibility. So, different kind of innovations (Herath, 2022; Rathakrishnan et al., n.d.; U.J.H et al., 2023)invented as a solution for this problem but practically they not used in that areas to minimize those accidents.

In India, Assam's elephant corridors have been severely affected by railway expansions, prompting mitigation strategies like underpasses and railway monitoring patrols. Similarly, in Kenya's Tsavo National Park(Kioko et al., 2008) examined the effectiveness of electric fencing and motion sensor technologies in reducing train and road collisions involving elephants. These international case studies illustrate that while fencing and speed regulations help, more advanced, location-specific technologies are essential for sustainable conflict reduction. The Sri Lankan context exhibits unique landscape challenges. Research by(Karunasena et al., 2024) emphasized that proximity to protected areas significantly increases the likelihood of elephant-train collisions. Their systematic GIS-based analysis showed that collision sites are much closer to national parks and wildlife reserves compared to random sites, disproving previous assumptions about water source proximity being the main factor. Furthermore, their findings revealed that collisions often happen farther from railway stations where trains reach higher speeds, indicating a need for strategic speed management policies. Historically, Sri Lankan authorities have attempted to manage HEC through the construction of electric fences, manual patrolling, and community awareness campaigns. However, electric fences often suffer from poor maintenance, lack of community cooperation, and elephant intelligence in breaching barriers(Fernando et al., 2019). Warning signs and vegetation clearance around railway lines were introduced, but their effectiveness remains limited due to driver non-compliance and elephants' unpredictable movement patterns.

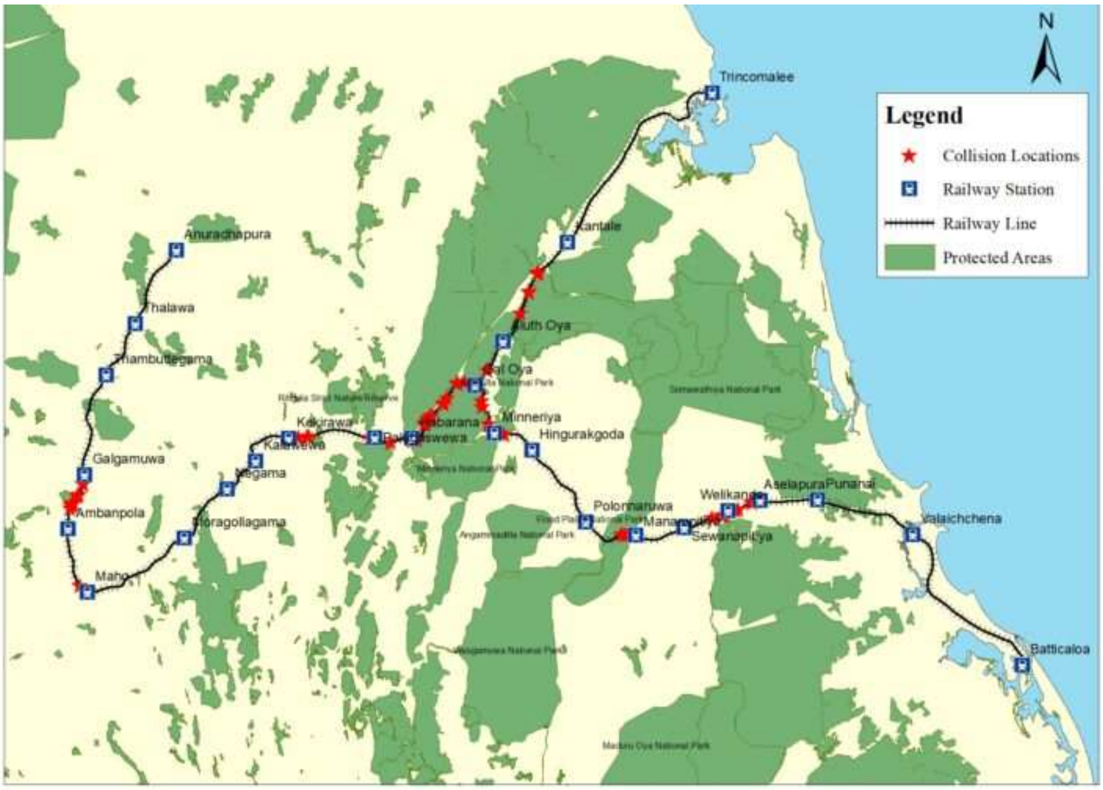

Figure 02: Areas Where the Train–Elephant Collision Occurred

Policy and technology interventions

These collisions began to occur in 2008, and despite short term solutions provided by the government, these collisions have continued to occur. Among the measures taken by the government.

According to(Gunawansa et al., 2023), the Sri Lankan government and railway authorities have introduced several policy-level interventions to address the growing issue of elephant-train collisions. These include implementing speed restrictions in high-risk railway segments, particularly during night hours when elephant movement is most frequent. Vegetation clearance along both sides of the tracks especially near curves has been carried out to improve visibility and allow train operators to detect elephants from a distance. Additionally, warning signage has been installed at known elephant crossing points to alert train drivers to reduce speed and exercise caution. Efforts have also been made to adjust train schedules, particularly limiting travel through key wildlife areas during peak elephant activity periods. Beyond the railway specific measures, community awareness campaigns have been launched to encourage local participation in elephant monitoring and conservation. The importance of protected wildlife corridors and buffer zones is also highlighted, though the study notes that the absence of a nationwide ecological corridor policy remains a major gap. Furthermore, compensation schemes and elephant relocation efforts have been initiated, but with limited success due to challenges in implementation and elephant homing behavior. Overall, the authors emphasize that despite these initiatives, enforcement remains weak, funding is limited, and inter-agency coordination is poor hindering the overall effectiveness of existing policies.

But although these measures have been implemented, they are not being implemented properly 51 train-elephant collisions have been reported between 2008 to 2013 and 63 train-elephant collisions have been reported between 2014 to 2020. Also ,67 elephant deaths have been reported in this period from 2020(Roy, 2022). Some existing policies don't account for new elephant movement patterns due to climate change or land development. For these reasons, the situation described above has arisen. The study by(Karunasena et al., 2024) provides critical scientific evidence that strengthens policy development aimed at reducing elephant-train collisions in Sri Lanka. Their findings highlight that proximity to protected areas is a significant factor influencing collision risk, rather than random chance or isolated human errors. This proves that policies must prioritize landscape management, such as the establishment and maintenance of ecological corridors, rather than solely relying on speed limits or warning signs. The research also shows that collisions occur more frequently farther from railway stations, where trains typically accelerate, emphasizing the need for strategic speed reduction policies specifically in zones adjacent to protected areas. Furthermore, the study supports the necessity for targeted mitigation efforts, such as the installation of AI-based early warning systems and the construction of underpasses only in identified high-risk locations, making conservation initiatives more cost-effective and impactful(Dinesh Deckker & Subhashini Sumanasekara, 2025). By providing concrete data linking landscape features to collision patterns, the study empowers policymakers to justify funding allocations, mandate environmental impact assessments for railway projects, and integrate wildlife conservation into national transport and infrastructure planning. Ultimately,(Karunasena et al., 2024) demonstrate that scientifically-informed, landscape-sensitive policies are essential to achieving sustainable coexistence between railway development and elephant conservationTrain-elephant collision continued to happen, various individuals and groups developed innovations using the latest technology and technological tool.

Table 01: Technological Solutions

No	Technology Solution	Description	Key Features
1	AI-Based Detection System	Real time elephant detection Using thermal imaging and Infrared sensors (university Of Peradeniya)	CNN algorithms, solar-powered, GSM alerts, works in low visibility
2	High-Frequency Sound Deterrent	Emits high-frequency sounds to deter elephants from railway tracks.	Motion sensors/manual trigger, non-invasive, elephant-sensitive frequencies
3	Arduino-Based wireless sensor Network	Uses multiple sensors (PIR, ultrasonic, seismic) with Arduino microcontrollers to detect elephant presence.	Low-cost, solar powered, GSM alerts, scalable
4	Fiber Bragg Gating (FBG)	Detects ground vibration using fiber optics to sense elephant movements.	High accuracy, underground installation, resistant to interference
5	GPS collars on Elephant	Tracks elephant movements through GPS, a past initiative by the Department of Wildlife.	Real-time tracking, behavior monitoring

The University of Peradeniya has pioneered the development of a real-time AI-based elephant detection system aimed at mitigating train-elephant collisions in Sri Lanka. This innovative system employs thermal imaging cameras and infrared sensors to detect elephants up to 500 meters ahead of oncoming trains. Using advanced machine learning algorithms, particularly Convolutional Neural Networks (CNNs), the system can accurately identify elephants even in poor visibility conditions such as nighttime, fog, or dense vegetation. Upon detection, automated alerts are transmitted through GSM networks to the nearest train stations and train operators, allowing sufficient time for trains to slow down or halt safely. Notably, the detection units are solar-powered, making them highly suitable for rural and forested regions where power infrastructure is limited. In addition to real-time monitoring, the system collects data on elephant movements, providing valuable insights for researchers and conservation planners. Although installation and maintenance present challenges, particularly concerning costs and network availability, the system signifies a major step toward harmonizing railway safety and wildlife conservation. Its success offers promising potential for future expansion, including integration with drone surveillance and edge AI technologies for a comprehensive railway-wildlife protection network.(Prof. Lilantha Samaranayake [PI], 2023).

Another notable technological intervention aimed at preventing train-elephant collisions is the Early Warning System utilizing high-frequency sound. This system is based on the behavioral understanding that elephants are sensitive to certain high-frequency noises that can act as natural deterrents without causing them harm. The system works by detecting the presence of elephants near railway tracks using motion sensors or manual observation. Once an elephant is detected, strategically placed speakers emit a calibrated high-frequency sound, typically in a range that is disturbing to elephants but inaudible or non-intrusive to humans. The sudden emission of these sounds encourages elephants to retreat from the railway lines, thereby reducing the risk of collisions. Trials have demonstrated that elephants often respond by moving away from the sound source, making this a non-invasive and wildlife-friendly method. The system is particularly useful at night when visibility is poor and in areas where physical barriers like fences are impractical. While it offers a cost-effective and relatively easy-to-deploy solution, challenges such as elephants eventually becoming habituated to the sound or the need for precise sensor calibration remain. Nevertheless, early warning systems based on high-frequency sound represent an important addition to the range of mitigation strategies for safeguarding elephants from railway accidents(U.J.H et al., 2023).

An Arduino-based wireless sensor network has been proposed as a low-cost, energy-efficient solution to detect elephants near railway tracks and prevent collisions. This system consists of multiple sensor nodes, each equipped with Passive Infrared (PIR) sensors, ultrasonic sensors, and seismic vibration sensors, all controlled by Arduino microcontrollers. The sensors continuously monitor the environment for signs of elephant movement. When an elephant is detected within a predefined range, the sensor node triggers an alert that is transmitted wirelessly via GSM modules to nearby train stations and operators. The entire system is powered by solar panels, making it sustainable and ideal for remote and rural regions where electricity access is limited. The network can cover large areas by linking multiple sensor nodes together, forming a distributed detection system. Additionally, Arduino platforms are highly customizable, allowing for easy upgrades or integration with other technologies like GPS tracking or high-frequency sound deterrents. While promising in terms of affordability and ease of deployment, challenges include sensor maintenance, signal range limitations, and the need for robust weatherproofing. Nevertheless, Arduino-based wireless sensor networks offer an innovative, scalable approach to minimizing human-elephant conflicts along railway lines(Herath, 2022).

The Fiber Bragg Grating (FBG) sensing system offers a highly sensitive and reliable method for detecting elephant movements near railway tracks, thereby helping to prevent collisions. FBG sensors work by detecting minute ground vibrations caused by the movement of large animals such as elephants. These sensors consist of optical fibers with specific wavelength gratings that change when subjected to mechanical strain, such as vibrations from elephant footsteps. When an elephant approaches a railway track, the vibrations generated are captured by the FBG sensors, which then transmit real-time data to a central monitoring system. The system can differentiate between vibrations caused by elephants and those generated by other sources, thereby minimizing false alarms. One of the main advantages of FBG technology is its high sensitivity and accuracy over long distances, along with its resistance to electromagnetic interference and harsh weather conditions. Furthermore, FBG systems can be deployed underground, making them less prone to vandalism or damage compared to surface-mounted technologies. However, challenges include the relatively high cost of installation and the technical expertise required for system calibration and maintenance. Overall, Fiber Bragg Grating systems represent a highly advanced and effective technological solution that, when integrated with early warning protocols, can significantly reduce train-elephant collision incidents in Sri Lanka(Rathakrishnan et al., 2024).

Although such inventions were created, the government did not pay proper attention and was more likely to occur. The GSP collars on elephant introduced by the department of wildlife was in operation but no rediscovered or improved after that. Technological interventions play a crucial role in early detection and proactive response to elephant movement near railway tracks. While many systems have shown promising results in pilot studies, the key challenge remains in scaling up these solutions across Sri Lanka's railway network and integrating them with government policy for long-term sustainability.

Conclusion

The ongoing train-elephant collisions in Sri Lanka particularly from 2020 to 2025 highlight a critical conservation and infrastructure challenge. Research has shown that habitat fragmentation, seasonal migration, and expansion of railway infrastructure into elephant territories are primary drivers of conflict. Technological interventions such as AI-based detection systems, Arduino wireless sensor networks, high-frequency sound deterrents, and Fiber Bragg Grating (FBG) sensing systems offer promising new approaches to mitigating these collisions. The University of Peradeniya's real-time AI alert system and other innovations demonstrate the potential of integrating modern technology into conservation efforts. Meanwhile, government initiatives such as speed restrictions, vegetation clearance, signage placement, and schedule adjustments show positive intent but are hampered by enforcement challenges, coordination gaps, and limited funding. Lessons from countries like India and Kenya suggest that combining landscape planning with real-time monitoring technologies can drastically reduce wildlife-vehicle collisions. Critically, the study(Karunasena et al., 2024) provides essential scientific proof that landscape factors particularly proximity to protected areas and train speed must be central to policy reforms. Therefore, future strategies must combine technological innovation, landscape-based planning, strong governance, and community engagement to build a sustainable coexistence model. Strengthened by data-driven insights and international best practices, Sri Lanka must prioritize ecological integrity within its infrastructure development to safeguard its endangered elephant population for generations to come. Despite various effort by the government including speed regulations and community awareness, the problem persists due to gaps in policy enforcement and limitations in technology deployment. Moving forward, it is essential for policymakers, conservationists, and technologists to work together in designing sustainable solutions that protect both Sri Lanka's national heritage the elephant and the safety of its railway system. Only through integrated and innovative approaches can a balance be struck between development and wildlife conservation.

References

Deckker, D., & Sumanasekara, S. (2025). *Systematic review: AI for wildlife conservation - Preventing elephant deaths from train collisions using artificial intelligence*. EPRA International Journal of Environmental Economics, Commerce and Educational Management, 78–98. https://doi.org/10.36713/epra20403

Fernando, S. P., Kobbekaduwa, H., & Kuruppu, V. (2019). Potentials and challenges of electric fences as a mitigation measure for the human-elephant conflict in Sri Lanka: A case of Moneragala and Ampara districts. *Upul Sanjaya The Central Bank of Sri Lanka 4 Publications*. https://www.researchgate.net/publication/336319692

Gunawansa, T. D., Perera, K., Apan, A., & Hettiarachchi, N. K. (2023). The human-elephant conflict in Sri Lanka: History and present status. *Biodiversity and Conservation, 32*(10), 3025–3052. https://doi.org/10.1007/s10531-023-02650-7

Herath, D. (2022). A systematic approach to avoid elephant train accidents in Sri Lanka using Arduino. *Horizon Campus Research Symposium*. https://www.researchgate.net/publication/368781081

Karunasena, T., Gunasekara, V. R., Wijesinghe, M., & Weerakoon, D. (2024). Assessment of landscape and railway features associated with elephant-train collisions. https://www.researchgate.net/publication/385242663

Kioko, J., Muruthi, P., Omondi, P., & Chiyo, P. I. (2008). The performance of electric fences as elephant barriers in Amboseli, Kenya. *African Journal of Wildlife Research, 38*(1), 52–58. https://doi.org/10.3957/0379-4369-38.1.52

Köpke, S., Withanachchi, S. S., Pathiranage, R., Withanachchi, C. R., Gamage, D. U., Nissanka, T. S., Warapitiya, C. C., Nissanka, B. M., Ranasinghe, N. N., Senarathna, C. D., Dissanayake, H. R., Perera, E. N. C., Schleyer, C., & Thiel, A. (2023). Human-elephant conflict in the Sri Lankan dry zone: Investigating social and geographical drivers through field-based methods. *GeoJournal, 88*(5), 5153–5172. https://doi.org/10.1007/s10708-023-10913-7

Prof. Lilantha Samaranayake [PI], Prof. K. M. L., Dr. N. H., Dr. T. W., Eng. S. R. G., Eng. T. A. from U., Prof. G. D. [PI], Dr. R. R., Dr. M. J. C. from U. of T. (2023). Saving giants: The elephant-train collision prevention system making headlines. *(Unpublished manuscript)*

Rathakrishnan, M., Mathushaharan, R., Peiris, M. D. C. D., & Wijewardhana, U. L. (n.d.). Annual sessions of IESL. https://www.researchgate.net/publication/386115577

Rathakrishnan, M., Mathushaharan, R., Peiris, M. D. C. D., & Wijewardhana, U. L. (2024). Annual sessions of IESL. https://www.researchgate.net/publication/386115577

Roy, M. (2022). Assessment of train elephant collisions in Sri Lanka. https://www.researchgate.net/publication/363290968

U. J. H. G., K. G. S. D. S., P. T. N. F., G. S. S., & Swarnakantha, N. H. P. R. S. (2023). Early warning system with high frequency sound to prevent elephant-train collisions. *International Research Journal of Innovations in Engineering and Technology, 07*(12), 164–170. https://doi.org/10.47001/irjiet/2023.712023