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continued on the back inside cover

Cover: Long-tailed Shrike *Lanius schach* resting on a dry branch after courtship. Digital illustration on Procreate. © Aakanksha Komanduri.

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COMMUNICATION

Impact analysis of SMS-triggered elephant activity alert lights

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Abstract: Human-elephant negative interactions typically arise when elephants enter human settlements in search of food, water, migratory routes, or other resources. Each year, accidental encounters with elephants in areas near reserve forests result in the deaths of hundreds of people. To address this challenge, the Bannerghatta National Park Forest Department has implemented a solution based on a straightforward conflict management approach, utilizing an SMS-based light and sound alert system to notify locals of elephant activity. To help reduce the risk of such encounters, 40 SMS-triggered elephant activity alert lights have been strategically placed across four ranges. We have partnered as the technology provider for this initiative. This paper presents an overview of the system's hardware architecture, the site selection process, the implementation strategy, and an evaluation of its technical performance and effectiveness over an eight-month period. This large-scale implementation of an elephant alert system offers valuable insights into potential usage in other conflict-prone areas.

Keywords: Accidental encounters, Bannerghatta National Park, forest department, human-elephant negative interactions, implementation strategy, socio-economic issue, sound alert system.

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Competing interests: The authors declare no competing interests.

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Author contribution: SD: Conceptualisation, methodology, resources, supervision, project administration, writing – original draft. SCSR: Investigation, data curation, field deployment, performance analysis. SA: Methodology, investigation, system development and implementation. SKR: Validation, formal analysis, writing – review & editing, correspondence.

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INTRODUCTION

Human-elephant negative interaction is a significant socio-economic issue in many parts of the country, particularly near reserve forest areas (Shameer et al. 2024; Natarajan et al. 2025), where ongoing habitat degradation has led to increasing elephant intrusion into settlements in search of food, water, and other necessities. Large-scale degradation of forests and the expansion of human settlements into traditional elephant corridors have intensified these interactions (Wilson et al. 2015; Majumder 2022). Elephant intrusions often lead to property damage and injuries/ fatalities of humans (Talukdar et al. 2024) and elephants alike. Providing early alerts of potential elephant activity could help to prevent such incidents and reduce the risks to both humans and elephants (Borah et al. 2020; Ramkumar & Deb 2021; Deb et al. 2025). In most cases, information concerning elephants leaving the forest comes from forest guards, watchers, local residents, and other spotters, many of whom have field experience in predicting elephantmovements (Ramkumar & Deb 2022). The challengeis to effectively communicate this information to the those in the local community who may be at risk of encountering elephants (Borah et al. 2020). In this context, the SMS-triggered elephant alert lights offer a highly effective approach to warn of local elephant activity and prevent potential conflicts.

Recognizing the need for such a system, the Bannerghatta National Park Forest Department has launched a project to install elephant activity alert lights (EAAL) at sensitive locations across four ranges of the park to improve human-elephant interaction management. As the technology partner, we have provided the design, installation, and maintenance support for 40 such system units. These EAAL units feature a PCB controller unit, GSM modem, battery, solar panel, light, buzzer, and other components. In collaboration with the forest department, 40 suitable locations were identified, and units were installed on 6 m (20 ft) iron poles for long-range visibility. The installation was completed in March 2024, and all of the units are now operational. This manuscript provides an overview of the project to date.

Design Architecture and Steps

The EAAL system hardware architecture comprises four primary subsystems: a controller unit, a light & buzzer unit, a power supply unit, and a communication module as shown in Figure. 1. The controller unit is equipped with a microcontroller that stores the program and integrates two relay switch modules to operate the light & buzzer unit. The system is programmed to activate the light & buzzer unit for varying durations upon receiving specific coded SMS messages, enabling short (10 min), medium (60 min), and long-duration (6 h) alerts as needed. The system also provides a stop code which needs to be communicated with the system to interrupt and stop the alert instantaneously. The light & buzzer unit consists of a 12 V waterproof module with two bright red lights and a compact 90 dB buzzer. The power supply unit features six 3 V rechargeable batteries in a parallel-series configuration, charged by a 12 V, 5-watt solar panel, ensuring a stable 12 V output and uninterrupted operation for 18–24 hours on a single charge. The communication module includes a GEM modem with a SIM slot, facilitating connectivity with the controller unit. The controller unit PCB is uniquely designed, while the system program has been developed based on inputs from key project stakeholders, including forest department staff and local residents, to align with the project's specific requirements. Figure 2 shows different steps of EAAL hardware system design.

Implementation Strategy

The EAAL system is designed to alert local residents about elephant movements, allowing them to take timely safety measures. To maximize its effectiveness, the system units are installed in or near human settlements at the forest boundary, preferably on elevated ground along frequently used paths. During field surveys, appropriate installation sites are chosen, often at village entrances or exits in high-conflict zones. The site selection process considers input from local villagers and forest officials. During installation, the system's functionality is thoroughly explained and demonstrated to the community. The system is triggered when a specific SMS code is received from any sender. As such, the contact number for the system and the activation code are shared with the designated forest guard and a few authorized local individuals. Each designated range is equipped with 10 system units. To ensure quick and direct communication regarding system-related issues, four WhatsApp groups, specific to each range, have been established, involving rangers, forest guards, and local community members. Pictures of system installation in collaboration with the forest department team and local residents are given in the Figure 3.

System Performance & Result Analysis

The performance of the EAAL system is significantly impacted by the strength of the mobile network and the positioning of the units for optimal long-range visibility.

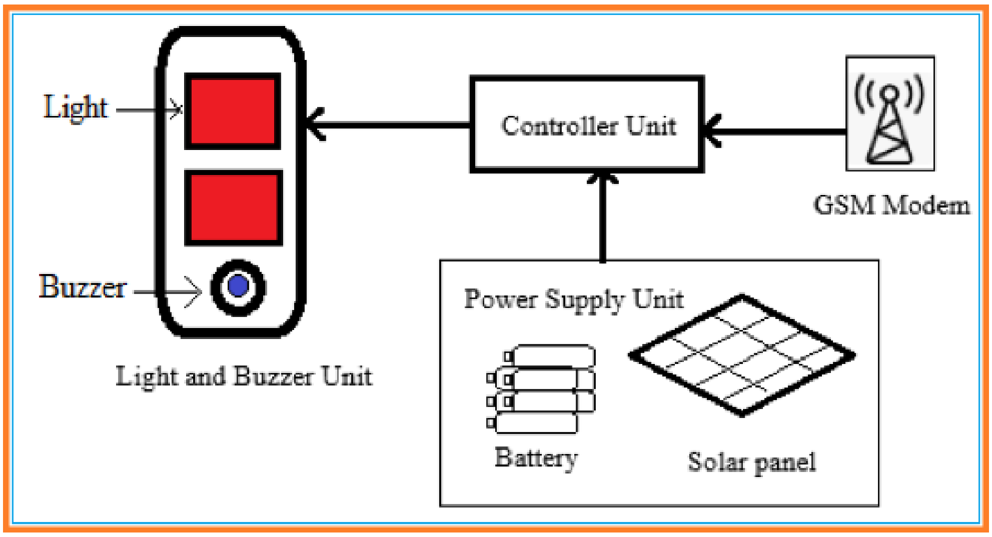

Figure 1. The architecture of the EAAL system.

Table 1. Range-wise numbers of unit with respect to network strength and suitable location.

	Range	Numbers of unit w.r.t network strength			Numbers of units w.r.t suitable location		
		Low network	Moderate network	Standard network	Village entry/ exit	Village inside	High-land/ open area
1.	Harohalli	3	5	2	4	3	3
2.	Bannerghatta	1	3	6	2	7	1
3.	Kodahalli	7	2	1	2	2	6
4.	Anekal	5	3	2	3	2	5

While some sites are strategically located for visibility from human settlements and elephant intrusion paths, they may suffer from weak mobile network coverage. Based on the current analysis, the network strength parameter is categorized according to call connectivity percentage: call connectivity of 80% or above is considered a strong network, 50–80 % connectivity is classified as a moderate network, and connectivity below 50% is regarded as a weak network. Therefore, choosing the best installation site requires balancing location suitability with network strength, necessitating careful optimization. To understand how this factor influences system performance, an evaluation of each unit's location in relation to mobile network strength has been conducted for all installed units, as shown in Table 1. The table indicates that the Bannerghatta Range, being near a major city, benefits from excellent mobile network coverage, with only one unit located in a low-network area. In contrast, Kodahalli, located at the interstate border, faces poorer network performance, with seven units in low-network zones. Harohalli and Anekal rank second and third, respectively, in terms of network weakness. However, system locations on elevated or open terrain offer superior long-range visibility and stronger mobile network connections, making them ideal for such light-based alert systems. Although Kodahalli has weak network coverage, its remote and sparsely populated nature makes it suitable for more system installations. On the other hand, Bannerghatta, which is densely populated, has most of its system units within the village itself. The other two ranges, Harohalli and Anekal, present intermediate conditions for system installation suitability.

As a real-time system, response time is crucial in determining performance, along with the number of failed triggering. Thanks to a strong mobile network, the Bannerghatta system units have an average response time delay of seven seconds, with three failed triggering, as shown in Figure 4. In contrast, the Kodahalli units, impacted by slow mobile connectivity, experience a higher average response time delay of 20 seconds, with seven failed triggering per unit. The other two ranges,

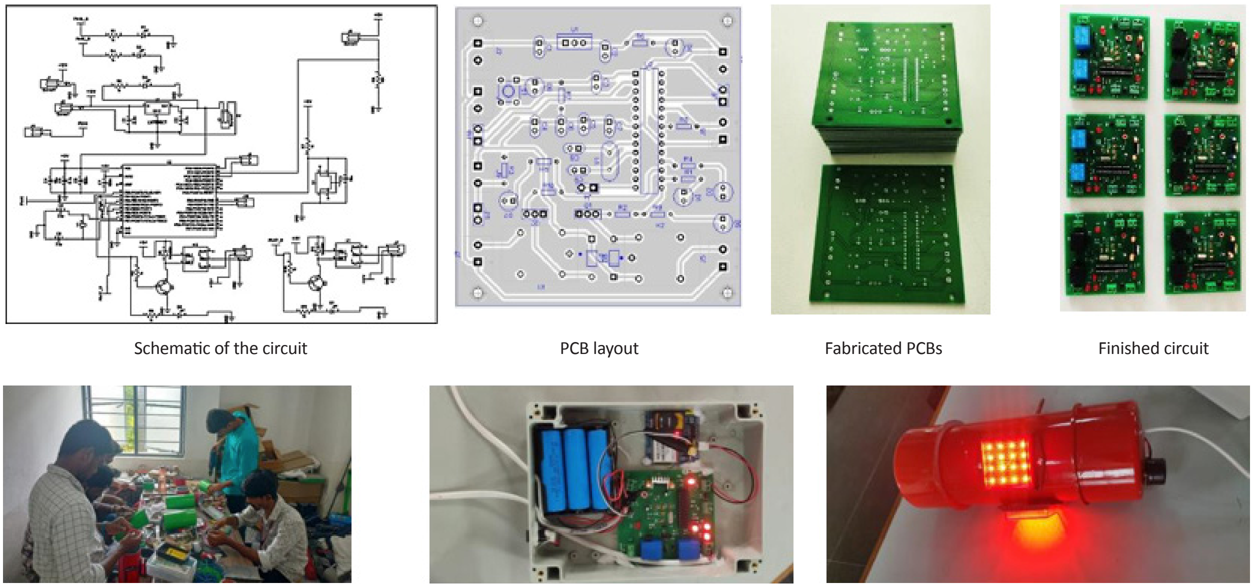

Figure 2. Different design steps of EAAL from scratch to the entire module.

Table 2. Range-wise system performance analysis.

	Range	Number of system trigger	Number of units out of range in days			Number of units suffered malfunction	
			+50	+100	+150	Count	Cause of malfunction
1.	Harohalli	10+	2	3	0	3	Circuit damaged (1 no) ant nests (1 no), water infiltration (1 no).
2.	Bannerghatta	30+	2	0	0	1	Light damaged due to water (1 no).
3.	Kodahalli	5+	1	4	6	4	Circuit damaged (2 no), a tree branch fell (1 no), and the pole was knocked down by strong winds (1 no).
4.	Anekal	7+	2	4	4	2	Circuit damaged (1 no), water infiltration (1 no).

Harohalli and Anekal, exhibit intermediate performance, with Harohalli ranking second and Anekal in third place.

Over the eight-month period of April–December 2024, the system's performance was analyzed based on the number of systems triggering via SMS, the number of units experiencing network failures, and the number of malfunctions, as presented in Table 2. Due to the quality of the network, the Bannerghatta system units were triggered more frequently, as shown in the table, compared to the other ranges. The data on triggerings, failed attempts, and units going out of network, was collected from forest officials assigned to each unit and updated on an ongoing basis through a WhatsApp group. Less than 20% of the system units malfunctioned during this phase, and these issues were primarily due to weather conditions and other factors, rather than circuit failures.

Although there are only four circuit failures, these circuits have been thoroughly investigated, and it has been determined that the 5 V relay switch is causing momentary high power consumption from the 5 V regulator during switching, leading to regulator damage due to overheating. As a result, the next generation of the EAAL system will be designed with a 12 V relay, powered directly from the battery, bypassing the regulator. To address the mobile network failure issue, the simplest solution is to restart the system to restore the network connection. Therefore, in the first phase of system maintenance, the units will be equipped with external hanging switches for easy restarts, which has significantly reduced the occurrence of systems going out of network.

During the installation and maintenance phases of the system, a survey was conducted to evaluate its impact on the local community, asking the simple question: "Do you think this system is useful and will have an impact?"

Bannerghatta Range | Harohalli Range | Anekal Range | Kodahalli Range

Figure 3. Installation of forty EAAL across all four ranges of Bannerghatta NP.

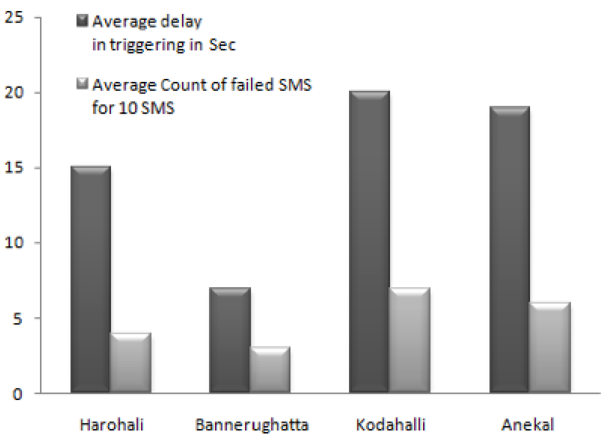

Figure 4. Range-wise average system response delay time with the number of failed SMS.

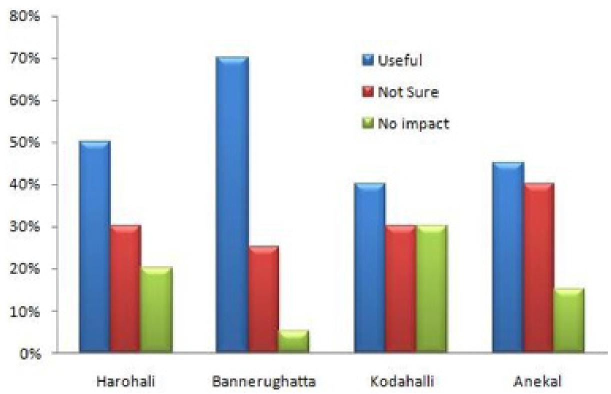

Figure 5. Range-wise local community response on system utility.

The sample sizes for Bannerghatta, Harohalli, Kodahalli, and Anekal were 100, 60, 50, and 30, respectively. The responses are shown in Figure 4 and Figure 5. Residents of Bannerghatta, a more developed and technology-friendly area, had a clear understanding of the system's benefits and gave positive feedback. However, in Harohalli and the other ranges, the responses were more mixed. This was due to a lack of technical understanding of the system and a preference for a deterrent system rather than an elephant alert system.

CONCLUSION

This research provides a comprehensive overview of a simple yet effective method for managing human-elephant conflict through a large-scale pilot project. The main goal is to alert local communities about elephant activity using an SMS-operated light and sound alarm system called 'Elephant Activity Alert Lights,' allowing them to take safety precautions. A total of 40 units of this system have been installed across four ranges of Bannerghatta National Park as part of a forest department initiative, with our technical support. The system is uniquely designed, and this paper outlines its architecture, design process, algorithm, and operation in detail. For the system to be effective, two critical factors—mobile network availability and long-distance visibility—must be considered. This paper includes detailed tables and graphs showing how these factors influence the system's performance and suggests possible ways to optimize it. The system's performance over an eight-month period is analyzed, including the number of times the system was triggered via SMS, the number of units experiencing network failures, and the frequency of malfunctions. These findings are presented with accompanying graphs and tables. Additionally, some technical issues observed during this period are discussed, and potential solutions for correcting them are identified. Local feedback on the system's usefulness on the ground is also gathered and presented. Given the significant socioeconomic and dangerous impact of human-elephant conflicts in many parts of India, this project, as detailed in this paper, will serve as a valuable reference for implementing similar solutions in other conflict-prone areas.

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