2020

Using design methods to identify opportunities to prevent train-elephant collisions in India

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Abstract:

Asian elephants are an endangered species of ecological and cultural significance in India. Human development activities frequently pose a threat to the elephant population in the country. Trains are believed to be the second highest contributors (after electrocution) to the unnatural deaths of elephants. With faster trains and a demand for connectivity, the threat to elephants and passengers alike due to elephant-train collisions is bound to increase. Addressing train-elephant collisions requires engagement with both the Indian Railways and the state Forest Departments. This project was an attempt to use participatory design tools and methods to involve grassroot stakeholders and identify opportunities to reduce train-elephant collisions within the scope of the operations of the Railway and Forest Departments. The stakeholders served as experts and were involved through qualitative discussion sessions to help us understand train-elephant collisions and ideate on the potential interventions. The problem was subdivided based on the major contributing factors which could each be tackled individually to contribute to mitigating train- elephant collisions: attraction of elephants to the track, detection of elephants on or near the tracks, conveying information about elephants on the tracks to relevant loco pilots, and easing exit of elephants from the tracks. Interventions to address each of these challenges are discussed.

Introduction:

Asian elephants are considered an endangered species by the International Union for the Conservation of Nature (IUCN, 2020)) and are placed in Schedule I of India's Wildlife Protection Act (1972) conferring it the highest level of protection (Baskaran et al., 2011). The current distribution of elephants in India is only a small fraction (about 3.5%) of what it once was about six thousand years ago (Baskaran et al., 2011).

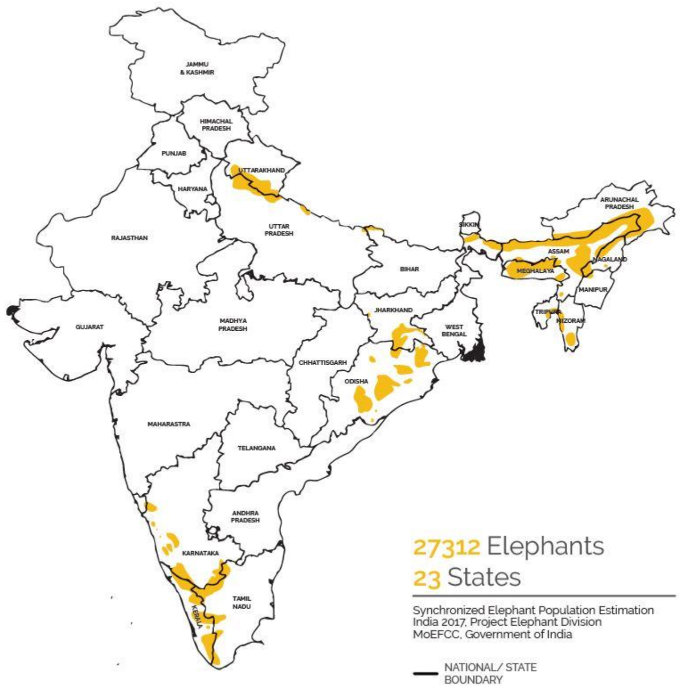

Figure 1. Distribution of elephants in India (Source: WWF-India)

Elephants experience pressure from habitat loss and fragmentation (IUCN, 2020; Leimgruber et al., 2003). Development projects such as irrigation projects, industries, mining, roads, human habitation and army camps have reduced elephant habitat and hinder the movement of elephants (Johnsingh & Williams, 1999). While most development projects pose an indirect threat to elephants by reducing the resource base available to support them, railway tracks pose a direct threat to the survival and well-being of elephants. Railway lines passing through elephant habitats in India have led to numerous accidents and the death of 249 elephants during 1987-2018 (V Sundararaju, Feb 2019, DTE) with 49 elephants killed between 2016-18 alone (S. S. Singh, 2020, thehindu). Accounts of these accidents describe elephants experiencing horrifying and painful injury and death (*Indiatimes, Sept 2019*). In addition to threatening the survival of an endangered species and resulting in dramatic animal welfare costs, such collisions also incur the risk of derailment and losses in terms of damages to the train and delays in operation for the Railways. With the Indian government investing in more and faster trains, including in elephant habitats (Roy & Sukumar, 2017), the threat posed to elephants and passengers by train collisions is bound to increase (St. Clair et al., 2020). This makes the issue a topic of interest for both the conservation community (including India's state Forest Departments) and the Indian Railways.

Figure 2. Visualizing a train accident that occurred in Chapramari in 2013.

Technology-based interventions like using machine learning to detect and estimate the distance of elephants from the train (Wijewantha et al., 2019) and anticollision devices (Deka & Sarma, 2012), although promising, may not always prove to be implementable because they may not integrate well into the existing Railway and wildlife management systems, be scalable, or otherwise operate in real-world conditions. Thus far, one of the most successful efforts to tackle this issue in India has been in Rajaji National Park through joint (low-tech) efforts of the Forest Department, Railways, and local NGOs (A. K. Singh et al., 2001). These stakeholders prevented elephant-train accidents through regular patrolling, sharing of information on the location of elephants, and setting up caution zones for trains to pass at a lower speed in high movement sections. These interventions worked in Rajaji NP in large part because the stretch of track was limited to just 18 kilometers (A. K. Singh et al., 2001), and thus they are not likely to be scalable. Nonetheless, the success of this intervention illustrates the potential of involving the concerned stakeholders to address the issue.

In this paper, we attempt to use a participatory design approach (Smith et al., 2017) to engage with key stakeholders to identify opportunities to prevent train-elephant collisions in India. The underlying assumption of this project was that developing an understanding of the causes of such collisions through engagement with stakeholders who are a part of the system in which collisions occur—and eliciting ideas for solutions from these stakeholders—would lead to more practical and implementable solutions to the problem. Our ambition was to come up with a toolkit of potential solutions that could be applied to site-specific (St. Clair et al., 2020) cases based on the factors influencing elephant-train collisions in that area.

Methods:

The project methodology can be divided into research, synthesis, and opportunity mapping. The process followed a double diamond structure (Nessler, 2016) where the research was divergent, synthesis convergent and opportunity finding having both diverging and converging aspects to it. A divergent approach aims to expand the scope by trying to find as many insights and opportunities as possible. A convergent approach is aimed at reducing the possibilities to select and focus on a few things that could be impactful for the issue.

Research: Secondary research involved research of accounts of previous elephant-train accidents and listing down possible factors causing the accidents to occur. A set of assumptions were made accounting for all the secondary research. This defined the goal of the primary research: to corroborate or contradict the assumptions. The best approach to do that was to have a participatory design process where the stakeholders play the role of the experts of the situation as they face the issue firsthand every day (Vandekerckhove et al., 2020).

The people who faced concerns of train-elephant collisions on a regular basis were our main experts to understand the issue, with information elicited though qualitative discussion sessions. The stakeholders approached ranged from those encountering the threat of collisions at the grassroot level to professionals focused on the issue. Most of our stakeholders were found in two regions where train-elephant collisions are known to occur: (i) in Rajaji National Park in Uttarakhand and (ii) in Sonitpur district and Lumding Reserve Forest area in Hojai district in Assam. Relevant stakeholders were identified by listing down all the roles that were directly or indirectly associated with elephant-train collisions while WWF experts attempted to represent the animal's perspective with respect to the issue.

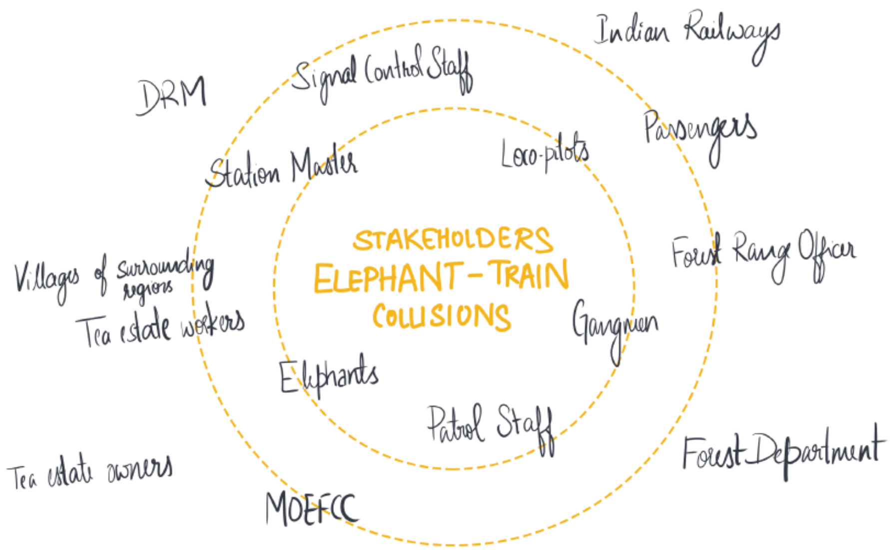

Figure 3. Stakeholders involved in the issue

Primary research began with qualitative interviews with grassroots level stakeholders combined with visits to sites where train-elephant collisions had occurred. Ultimately, a total of 37 stakeholders in Uttarakhand (N=13) and Assam (N=24) were consulted. These stakeholders included: Loco pilots (N=20), Gang men (N=4), Stationmaster (N=2), Forest Guards (N=10), and Forest Department range officers (N=2). Interviews were also conducted with four professionals associated with WWF-India.

Clockwise from top: Figure 4. Discussion session with loco pilots at Rangapara station, Assam, Figure 5. Discussion session with loco pilots at Dehradun, Uttarakhand, Figure 6. Forest Department team at Sonitpur, Assam, with WWF India staff.

The first objective of the qualitative interviews (refer appendix for a list of primary questions) was to gain an understanding of what caused such accidents. The factors considered were limited to the design, operations, and management of the Railways and did not delve into the longer-term or large-scale factors like habitat fragmentation. The second objective was to generate ideas and get input on possible solutions. In some of the discussions, tools for visualizing the conditions (figure 7) faced by the loco pilots were used. These tools included cutouts of various forms of vegetation, types of tracks, indicators for time of the day and environmental conditions to choose from. These became aids to help respondents visualize and communicate (Lauff et al., 2020) the possible reasons that could prevent them from detecting elephants along the tracks. Visits to previous accident sites also helped visualize accidents that had happened and the circumstances leading to those accidents. Visits were made to Chapramari, West Bengal; Sonitpur, Lumding, and Rangapara in Assam; and Rajaji National Park in Uttarakhand. The field visits and documentation helped us test assumptions and find new insights regarding the problem.

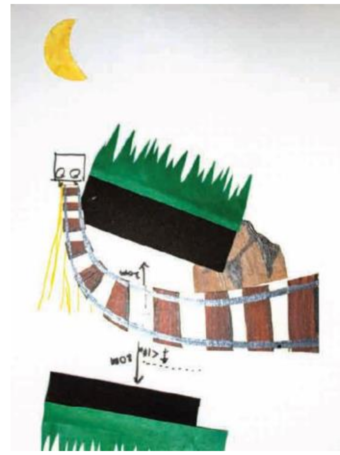

Figure 7. Visualizing tools that were used in one of the discussions with the loco pilots. Figure 8. the tool in use by loco pilots to describe issues faced.

Synthesis: The factors contributing to train-elephant collisions such as weather conditions, terrain, and attractants that drew elephants to/across tracks were sorted into subframes and reassessed with the stakeholders involved, helping break down the complex problem into more manageable pieces (Dorst, 2015). The factors were also categorized as universal or area-specific, and what (if any) previous efforts had been taken to address them were noted. This allowed us to analyze the scope and extent to which a certain responsible department could be accountable and take actions to help mitigate these accidents.

Each of the potential solutions proposed either during discussion sessions or subsequent ideation was then also sorted into the subframes. We filtered these potential ideas by rating the ideas based on simplicity, impact, buy-in, cost, achievability and whether the solution would be universal or limited to an area. This exercise helped identify promising potential solutions.

Concept Evaluation

	Concept (UNDESIRABLE 0-5 DESIRABLE)	Simplicity of solution(dif-easy)	Buy in / Implementation (dif-easy)	Impact of solving the problem wrt to mitigating the issue.(low-high)	Self sustainable solution (ability of the solution to work without external intervention after implementation)	Possible cost of implementation(high-low)	Achievability in 4 months (lo-hi)	Longevity of solution (Short term-long term)	TOTAL	Tezpur	Rajaji	Comments
Develop and provide tool/system	*Ways to warn locopilots directly- While patroll staff is along the*	*5*	*4*	*2*	*4*	*5*	*5*	*L*	*25*	*0*	*1*	*Should be easy to set up but but Impact isn't so much. Could be detailed out and suggested but isn't one of the main things to work on.*
Develop and provide tool/system	*Visibility solutions for bends/curves*	*4*	*4*	*4*	*4*	*3*	*3*	*L*	*22*	*0*	*1*	*This seemed interesting to me because of the possibilities which could be simple and easily implemented. But this would be applicable only in identified places for the set of conditions.*
More information	*Involvement of gangmen and public in aiding efforts*	*2*	*4*	*3*	*2.5*	*4*	*4*	*L*	*19.5*	*1*	*1*	*I have not yet interacted with either gangmen or public but this might have to be incorporated into a larger system.*
More information	*Incentives*	*4*	*4*	*2*	*1*	*2.5*	*5*	*5*	*18.5*	*1*	*1*	*The Locopilots in both regions acknowledge the value of an incentive. This might not actually contribute to solving the issue but would help making a stressful job feel worthwhile. It could also help spread the message of the existance of the issue with a positive note.*
Develop and provide tool/system	*Solution for better visibility for locopilots*	*2*	*5*	*4*	*2*	*2*	*3*	*L*	*18*	*1*	*1*	*This was one of the key issues picked up by locopilots. Without seeing the animal the animal cannot be saved. The explorations would have to be : 1.How to see the animal on track? 2.How to know of an elephant on track even if it isn't visible?*
Support existing initiative	Garbage on tracks	1	4	3	4	3	3	L	18	0	1	Garbage on tracks is a regional issue without much evidence of the number of animals getting attracted to the garbage. Although this might not be contributing much to this issue it would surely have a positive impact in the general problem of littering and trains. The things to be addressed here would be:1.A system of garbage collection and disposal 2.Communicating the issue to different contributors and bring about behaviour change.
	Declaration of caution zones	1.5	1	4.5	4	4	2.5	L	17.5	1	0	The declaration of caution zones and their validity and relavence to elephant movement is a major pain point especially in Tezpur where often declared zones would become redundant. But to address this issue there has to be a knowledge base that can record or predict elephant movement. Instantaneous caution zone declaration works well in a defined setting such as Rajaji where there is constant monitoring and communication.
more information	Alternatives for shock absorption	2	2	4.5	2	2	2	L	14.5	1	1	Needs to be discussed with an engineer in the railways. Whether the sharp stones actually hurt the elephants would have to be considered.

Figure 9. Evaluation of possible solutions based on simplicity, impact, cost, region, etc.

Results:

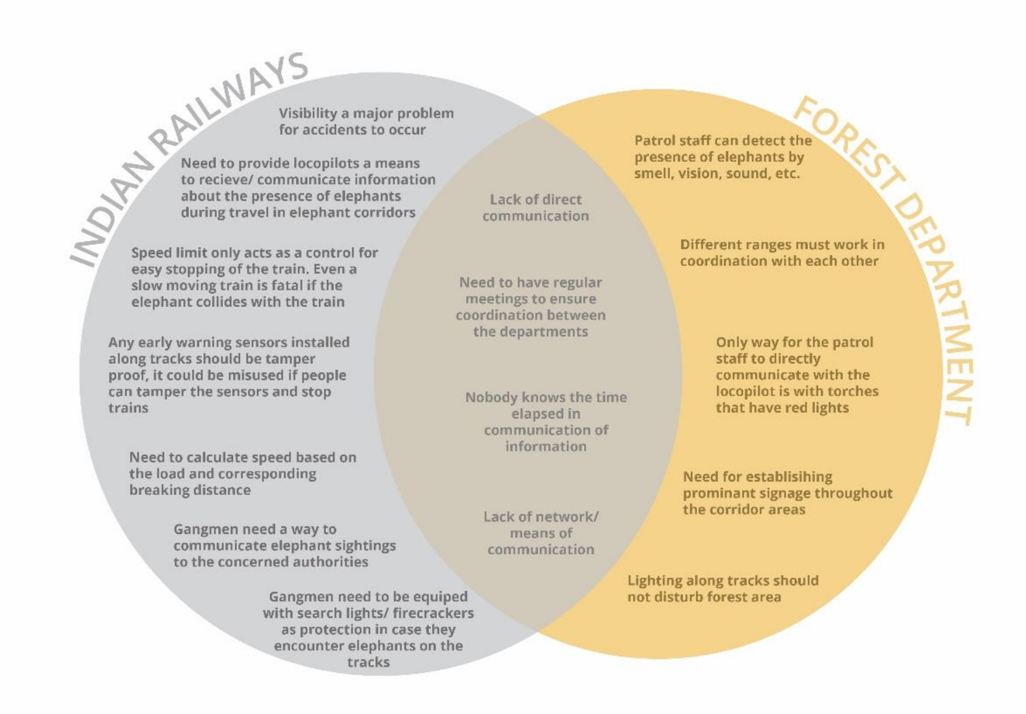

Figure 10. Mapping insights on the issue based on departments concerned

Five major subframes covered all of the factors identified in the study that might be contributing to train-elephant collisions and that were within the scope of the operations of the Railway and Forest Departments. The five subframes were as follows:

Elephants attracted to being on or around the railway track

Elephants might come near train tracks for two main reasons: first, if the track lay in the path of the elephant as it goes from one place to another (note that landscape-level factors are beyond the scope of this study), and/or second, if there is something on the track attractive to the elephant, like food. Particularly in Rajaji NP (and not in Assam), trains and passengers dispose of their food waste on the tracks, attracting many animals including elephants. Elephants eating these foods might spend more time on the track than they would otherwise, increasing the risk of the elephants being struck by trains. In principle, this issue could be managed through effective garbage disposal systems (that don't leave food on the tracks) and increased passenger awareness of the impact improper food disposal could have on animals. Passengers could be educated through announcements in the trains, railway stations around Rajaji National Park, posters, and other awareness material which would describe the impact irresponsible garbage disposal would have on wildlife. The catering staff can be sensitized through awareness drives and workshops. But such awareness campaigns can only be effective if a proper garbage disposal system is in place.

Figure 11. Poster for travelers to convey the impact of throwing garbage

Difficulty in detecting the presence of an elephant near a track in time to prevent a collision
Spotting elephants in time to prevent a collision was made difficult primarily by fog and curves in the track. In Assam, elephant movement was observed more during the winter months when the fog is dense. As such, elephants were not visible to the loco-pilot in time to prevent the accident. Improving visibility during nights and dense fog would significantly contribute to avoiding future accidents. This issue can be approached through site-specific interventions along the tracks and interventions made to the train to improve visibility.

One of the on-track interventions would be to install lights along the tracks such that visibility can be improved. The intervention would involve a system of solar-powered lights along the tracks which can be triggered to be switched on by the proximity of the train through GPS— every train is already GPS tracked. These lights would normally be in a switched-off state. Whenever an approaching train reaches the proximity of 2400m (twice the minimum braking distance of a full-speed train) from the light, the light will be triggered on (figure 12). This could significantly improve the visibility for the loco pilot. This kind of intervention is valuable in two additional ways:

- Setting the lights to be triggered to switch on a few minutes before the train arrives ensures that there is no significant disturbance to the surroundings by keeping lights on throughout the night.

- The animals will have a reaction time to help them get away from the tracks. This will prevent the animals from getting stunned and could eventually act as a visual cue for animals of an approaching train.

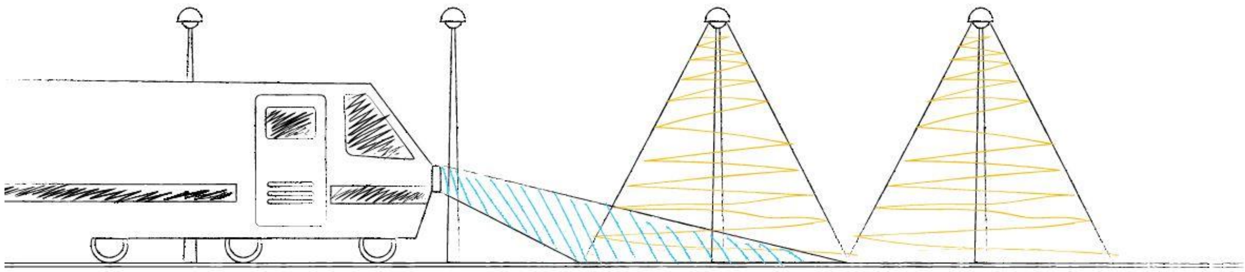

Figure 12. Schematic of solar powered GPS triggered lights

This kind of a solar-powered lighting system that can be triggered remotely is already developed and available in the market for a different purpose. Adapting a product to fit the current purpose would ensure ease of use, maintenance and availability while being a low-cost intervention.

On-train interventions would include better lighting and fog lights installed to aid the loco pilot to see better. Another possible intervention is the TRI-NETRA system(*Railways Conducting Trials of Tri-Netra Technology - The Economic Times (June 28, 2019)*), under development by the Indian Railways, which aims to provide assisted vision to the loco pilot through a combination of thermal imaging, RADAR, and optical imaging.

In some sections when there are curves, loco pilots have reported that the directionality of headlamps poses a problem: the headlamps shine directly ahead, and the curve becomes a blind spot for the loco pilots. Inspired by the automotive industry, if the train's lights could be made automatically directional, this issue can be resolved. Automotive lights align themselves based on steering location, but unfortunately, this is not possible in the case of trains. An alternative is a gyroscope-based system in which a directional sensor can be used to align the lights based on the direction of motion of the train (figure 13). A servo motor powered lighting system coupled with the gyroscopic sensor would make a functional directional lighting system.

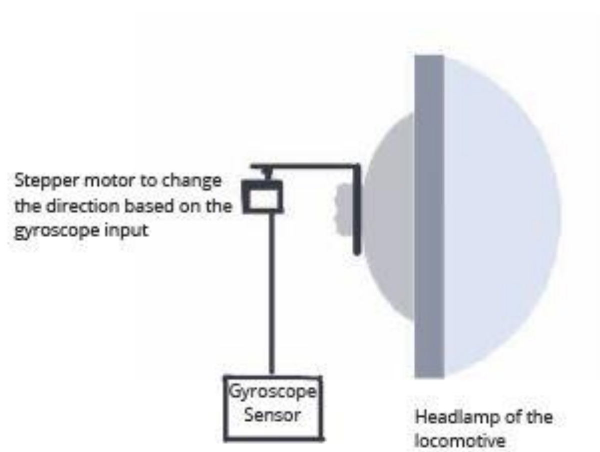

Figure 13. Representation for a directional headlamp

Problems in communicating the information to the loco pilot in time to prevent a collision
The passage of elephants in an area is generally witnessed by people. Be it locals, gang men tending to the tracks, gatemen at the gate crossings, Forest Department patrol staff or even some loco pilots. However, this information needs to be communicated through a chain of command to result in any form of action. There is also a significant amount of confusion in communicating the information between these sections of people. A Forest Department personnel might informally inform someone in the railways about the presence of elephants by sharing the GPS location or indicating a nearby village or other such references. But the Railways Department have an alternate system of sectioning their railway tracks, meaning they might not understand the location as communicated by the Forest Department. Having informal communication systems also means this information is not officially recorded and can be easily missed in the clutter of personal messages. All this might result in the loss of time and lack of timely action.

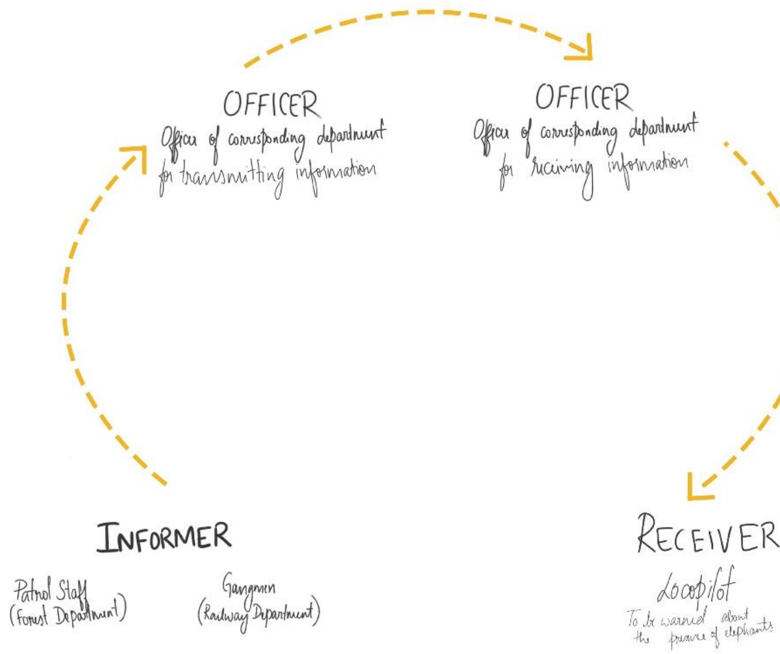

Figure 14. Current system of information transfer between informers and loco pilots.

A formalized communication platform would significantly reduce this confusion and maybe even help in getting the information to the loco pilot faster. Information about the presence of elephants is crucial to avoiding accidents as extra caution can be taken in such sections. An ideal communication system would have open access to enter information regarding the presence of elephants for all the people using the application/platform while also having certain authorities being able to approve and disapprove such information which ensures reliability of the system. This would allow the establishment of dynamic caution zones based on the movement of elephants. Such a system would have informants like patrol staff, locals, gatemen, and loco pilots while there will be a few positions like station master and range officer who can access, modify, and approve/disapprove a caution. The end-users in this will be loco pilots, station control room officials who are responsible for managing railway traffic, and (to a lesser extent) the Forest Department staff who know the presence of elephants near railway tracks. The loco pilots need an intuitive interface with just enough information regarding recommended speed and identification of the sections in which elephants might be present. This can either be done through existing systems (which would be preferred) or through having an additional screen in the dashboard that is currently used by the station control room to issue cautions and manage railway traffic.

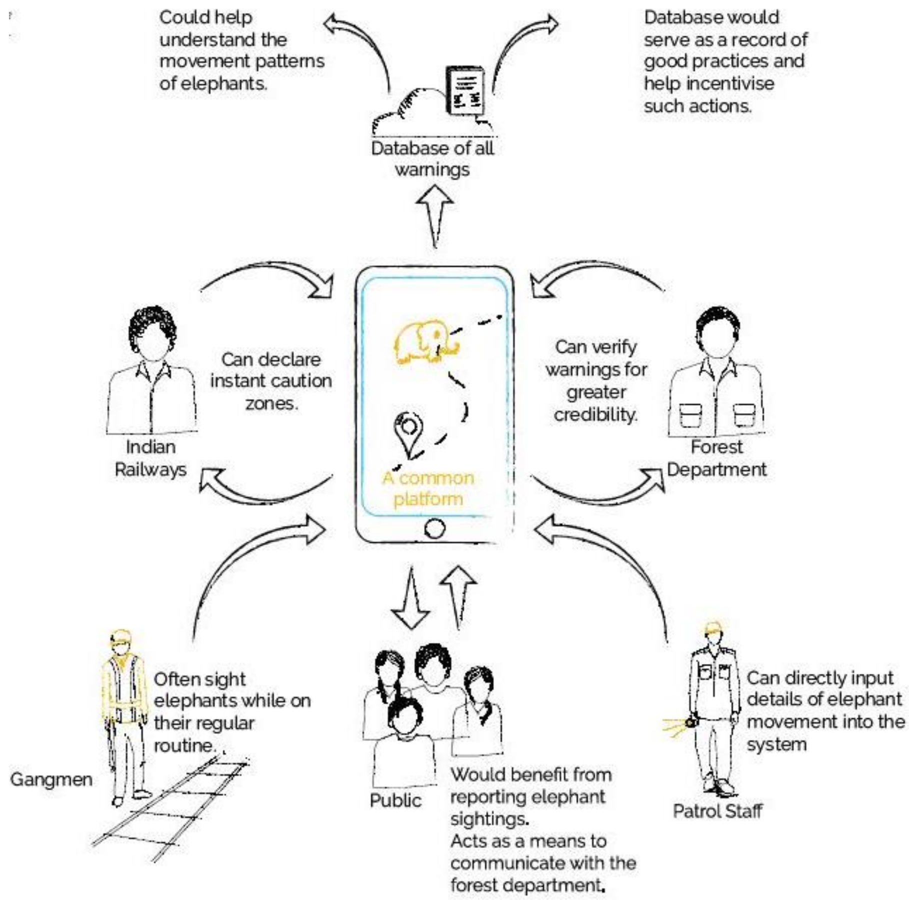

Figure 15. Proposed system of communication

Elephants struggling to escape an approaching train

Elephants sometimes might realize that a train is fast-approaching but find themselves unable to get off the track. This could happen for several reasons. One, they have walked onto a stretch of track that has impediments to their movement off the track on either side, such as fences or deep drains. This could be addressed through site-based analysis and ensuring that elephants do not get forced to walk on or next to the track. Long fences create a tunnelling effect for elephants, increasing the chances of an accident. Having elephant-proof barriers to divert elephants from getting onto the tracks in such sections is required in case such fences are necessary. For gutters/ drains providing easy passage for elephants (even calves) at sections that elephants are known to frequently cross needs to be considered.

Additionally, elephants have been observed to struggle to cross railway tracks due to the sharp ballast that hurt their feet. This makes it difficult for them to make a quick escape even if they detect an approaching train. An alternative to this, recommended by a Railway authority, could be to install patches of washable apron at stretches where there is frequent elephant movement. This would help ease the movement of elephants. This would also help maintain strict caution zones as the washable apron allow trains to travel at only 30 kmph. Such interventions are much more likely to be adopted than many other interventions since the procedure to install/ setup the infrastructure already exists within the Railways system. Using already developed systems for this cause will also significantly reduce the cost involved in developing and implementing such solutions.

Figure 16. Left: ballast on tracks. Right: Washable apron (source NEFR Railways website)

Discussion

We endeavored to use participatory design principles to find potential solutions to train-elephant collisions that were compatible with existing Railway and Forest Department systems, particularly in Uttarakhand and Assam. By engaging with stakeholders as experts, we both confirmed already known elements of what cause the collisions as well as identified new, context-specific factors and solutions. Prior observers have noted that foraging opportunities along railway tracks increase mortality risk (Kušta et al., 2011), and that food and garbage disposal are a particular danger to wildlife (A. K. Singh et al., 2001). The role of detection has also been explored: commentators have noted that most accidents happen at night when visibility is low (How to Save India's Elephants from Killer Rail Tracks, V Sundararaju Published: Wednesday 06 February 2019), and others have tried to address issues of detection and communication (e.g., (*IIT Prof's Answer to Jumbo Deaths in Train Collision- The New Indian Express , 03rd January 2021*),(Deka & Sarma, 2012), (Pavlović et al., 2018)).

Our approach led to the identification of specific interventions that could leverage relatively less complex (and often already available) technologies that are more compatible with existing Railways systems and might even have substantial cobenefits. For instance, fog lights that could reduce the probability of train-elephant collisions already exist and would generally improve the functioning of the trains during fog. Furthermore, the interventions identified aim to strike a balance between reliance on technology (which must be maintained and can be expensive) and labor-intensive human involvement (which might not be sustainable at a systems level). Still, the solutions we identified need to be tweaked and tailored on a site-by-site basis.

Our next step using this research is to engage the leadership of the Railways so that such site-specific engagement with stakeholders and analysis can be conducted to identify which interventions should be applied. These analyses will be used to make site-specific recommendations on what interventions to immediately implement and develop. Hopefully, further engagement with these stakeholders will then translate to a reduction of train-elephant collisions.

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Appendix

Primary questions for the stakeholders

Stakeholder	Questions
Loco pilot	1. Number of animal crossing encounters (average)
	2. Region of work
	3. Average work hours
	4. Do you remember a train accident that happened recently? Describe (What do the describe about the accident? Who do they find fault in? do they relate to it?)
	5. Any accident that you were involved in or managed to avoid? (if yes)
	a. When: Date, Time, season/ weather conditions
	b. What part of their work hour did the accident happen? (was fatigue a factor?)
	c. Describe the accident (understand the process of decision making)
	d. What were the damages that were incurred? (elephant, train, passengers, time)
	e. Repercussions of the accident (To understand the seriousness with which the Railways view the issue)
	6. Attitude towards the elephants/ other animals crossing
	7. What if: You weren't warned but an elephant comes on track. Would breaking be a possibility without hurting passengers? What would you do? (thought process behind decision taking)
	Broader cues for observation
	The attitude of Loco pilots towards elephants, initiative/ willingness to change.
	The thought process behind decision making at the time of crisis.
	To understand if the gravity of the situation is perceived by the loco pilots.
	Damage that is incurred by the Railways due to such accidents.
	Things that prompt shifts in behavior.
	Work arounds/ adaptations.
	Things they care about (train, people, animals, morals, fear).
	Any opinion or insight which might be based on their experiences in facing the issue.
	Anything that questions my assumptions made through secondary research.
For WWF experts:	1. Working of the SMS/WhatsApp system
	2. Possibilities of long-term usage. Dependency of the system on cooperation and community involvement.
	3. Involvement of WWF in keeping the system alive? Could it become a self-sustaining system?
	4. Distance through which the train travels in Rajaji vs patrolling distance.
	5. Predictability of elephant crossing. At what point could one be sure that the herd is going to cross?

	6. Are there any incentives or rules in place for the system to work? If incentive based, then would the incentive be relevant in the future.
	7. Rhinos vs elephants. Why do rhinos not get caught in such accidents?
For Patrolling staff:	1. Conditions under which they work
	2. How do they communicate?
	3. Groups
	a. Always the same group?
	4. Group dynamics
	5. Regarding any record of elephant movement near or across railway tracks.