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GIS-BASED MAPPING AND TEMPORAL ANALYSIS OF RAILWAY ACCIDENTS IN BANGLADESH

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ABSTRACT

The issue of the safety of railways is particularly urgent in Bangladesh where an increased demand of both passengers and freight, the deterioration of the railway infrastructure, and the difficulties with proper functioning of the railway system makes the possible accidents more dangerous. Although the railway industry is very important in the development of the country, the common occurrence of collisions, derailments, and level crossing accidents are threatening the lives and productivity of the people. The research is based on a GIS-based spatio-temporal framework to examine the railway accident in all the divisions of Bangladesh during the period of 2000 and 2024. Secondary data were obtained through Bangladesh Railway reports, newspaper archives and government publications and were compiled into a full geodatabase. Spatial analysis was performed, such as hot spot mapping with the Getis-Ord Gi+ statistic and the Kernel Density Estimation, as well as the temporal trend analysis to determine the accident-prone place and time. The findings show that the clusters of accidents are highly localized around the large routes like Dhaka-Chattogram and Dhaka-Khulna with human error, mechanical failures, and inadequate infrastructure found to be the most frequent causes. Seasonal weakness is indicated in the temporal analysis, which indicates that there are more accidents during monsoon months and seasons with the highest levels of traffic congestion. Relative evaluation against the data of the Indian railway accidents reveals that human error is also common but material failure has a higher percentage in India. It is on the basis of such findings that the study advises adopting a multi-faceted solution in increasing the level of safety in the railways, which involves technological enhancements like automated train control, electronic signaling, infrastructure modernization, better employee training and institutionalization of GIS based accident surveillance systems. These measures should help reduce the risks of accidents and enhance the efficiency of operations and evidence-based decision-making by the railway authorities and policymakers. The combination of space and time allows the given study to gain an overall picture of the railway accidents in Bangladesh, discover key hotspots and time trends that can help to make informed safety interventions

Keywords: *GIS, Railway Accidents, Spatio -Temporal Analysis, Hot Spot Analysis, Bangladesh Railway Safety*

1. INTRODUCTION

The rail transport is significant in the overall system of transport in Bangladesh as it provides the mode of transport at a low cost, efficient, and environmentally friendly to move a passenger and freight. The country has an extensive train network with over 3,000 kilometers of railroad track in Bangladesh Railway, now a national connector, because it is currently connected to major cities, ports, and factories. This system does not only enhance the mobility in the region but it also plays an important role in the economic growth of the country. The Chittagong Division in this network is particularly strategically important because it links the biggest seaport in Bangladesh at Chattogram to Dhaka, Sylhet, and many other industrial hubs, and hence serves to be a lifeline of trade and commerce.

Though this is a crucial part, the Bangladesh railway industry has been experiencing chronic safety issues. Its infrastructure is described as old assets and limited modernization processes, as the passenger and freight services are both increasing at high rates. These circumstances increase the possibility of accidents, and collisions, derailments, and level-crossing are rather common. The causes of such accidents are usually associated with human factors, mechanical, malfunctioning of the signaling system and environmental hazards like flooding caused by monsoons. The effects are also dire as they do not just lead to loss of lives and injuries but also deprived service, loss of economic gains and low civic trust in the use of railways means of transport.

To overcome these obstacles, it is necessary to employ sophisticated analytical solutions that will be able to combine sophisticated data sets and deliver practical results. Geographic Information Systems (GIS) have become an effective tool towards railway safety research and management in this respect. GIS can be used to combine both spatial and time related data of railway accidents so that the hot spots of accidents, high-risk corridors, and the pattern of accidents can be determined by season. These analytical processes can help decision-makers and practitioners to develop specific interventions in order to reduce risks and enhance the resilience of the systems.

Based on these opportunities, the current paper uses GIS-based methods to conduct a systematic study of the railway accidents in Bangladesh in the years 2000-2024. The research objectives are threefold: to map the spatial and temporal distribution of railway accidents; to investigate the causative factors and contributing influences; and to suggest the action plans to improve safety, reliability, and operation efficiency within the railway system of the country. The research will help to make evidence-based policymaking and the sustainability of the railway industry in Bangladesh over the long term through the synthesis of the spatial analysis and viable recommendations.

In developed nations, much research has been done on safety in railways, systematic examinations, enhanced safety technologies, and frame worked methods of monitoring have been put into practice in order to reduce accidents. They highlight the importance of preventive actions, automation, and effective infrastructure in preventing the number of accidents and promoting reliability of the operations. On the contrary, studies on railway accidents in Bangladesh and South Asia, in general, are still rather scarce, and there are serious gaps in knowledge concerning the causes and the possible mitigation measures to be used in the regions. According to the existing research, the main causes of railway accidents are human factors, deterioration of infrastructure, and insufficient signaling (Ahsan & Islam, 2015; Agarwal, 2005). Comparative studies involving India have pointed out that, in as much as human error is the leading cause in both countries, material failures and supply shortages are more prevalent in India indicating that the system has weaknesses in the area of operational resilience (Agarwal, 2007). These results imply that human-based interventions are important but infrastructural and systemic changes are as well required. It has been noted that Geographic Information Systems (GIS) has been used in the study of railways safety due to its capability to combine and analyze the spatial and temporal accidents. GIS enables mapping of clusters of accidents, setting up high-risk paths, and illustration of a variation across seasons, which provide evidence-based information to focus on interventions (Azzacy & Islam, 2014a). These spatial methods do not only enhance the knowledge of the patterns of accidents distribution but are useful decision-support instruments to the policymakers and railway authorities. The other aspect that has been highlighted in the study of international rail safety is related to the robustness of the system, which can be defined as the abilities of a railway network to maintain a safe and uninterrupted operation in the event of multiple disruptions (Andersson, 2014). Research studies show that the infrastructure of the railway system of Bangladesh is very weak because of poor infrastructure, use of ancient technologies and use of reactive maintenance as opposed to preventive maintenance. This weakness highlights the importance of the need to implement modernization measures and systematic safety management approaches to improve resilience. Although in world literature, the knowledge about the causation of accidents, resilience, and the usefulness of GIS-based safety analysis is rather rich, it is not yet researched in relation to the railway industry in Bangladesh. Such gap can be bridged by context-specific studies that combine spatial analysis with the resilience-based strategies. The infrastructure reinforcement, modernizing signaling and control systems and adopting GIS-based monitoring systems might make Bangladesh railroads much safer and more reliable in their functioning.

2. METHODOLOGY

2.1 Data Collection

The research is founded on the secondary sources of data as the primary ones, yet the source of the information should be the systematically gathered and publicly released records of railway accidents. The major sources are news reports, Bangladesh Railway Automated Support System (BRASS), Centre of Railway Information Systems (CRIS) and the Real-Time Train Information System (RTIS). Such databases offer comprehensive records of the accident incidents, operational interruptions as well as safety performance measures that are crucial in the analysis of spatial and temporal accident trends in Bangladesh as well as in the comparative analysis with India. The data reporting methodological approach used is also a process of collecting, classifying, and reporting organized railway accident data to allow proper interpretation of an occurrence on the trackside (BRASS, 2018; CRIS, 2019; RTIS, 2020). This method provides the uniformity of datasets and the opportunity to cover the range of accidents types, locations, times and causes. Accident data provided by BRASS was also compared with newspaper archives and government publications to increase the reliability of results, thus minimizing reporting biases. CRIS and RTIS data also helped uncover systemic problems like signal failures, train delays and bottlenecks in operation. Combining these sources, the basis of GIS-based spatio-temporal analysis is strong, and it is possible to identify the hotspots of accidents, seasonal trends, and the reasons that triggered the railway accidents in Bangladesh.

Table 1: Summarizing some of the notable train disasters in Bangladesh's history:

Date	Location	Incident Details	Casualties	Cause
January 15, 1972	Jessore	A train derailed at Jessore, killing 76 people.	76+	Mechanical failure
December 4, 1989	Gazipur	Two trains collided head-on at Gazipur near Dhaka.	170+	Human error
May 13, 1995	Tangail	A passenger train collided with a freight train near the Tangail district.	50+	Human error
January 17, 2010	Narsingdi	Two trains collided at Narsingdi Station.	14+	Signal failure
June 23, 2019	Moulvibazar	A train derailed and plunged into a canal in Moulvibazar, Sylhet.	5+	Poor track conditions
November 12, 2019	Brahmanbaria	A collision between two trains at Kasba in Brahmanbaria District.	16+	Human error
August 1, 2022	Dhaka-Tongi Line	A collision between two passenger trains occurred near the Tongi area.	12+	Signal failure and poor track

This table covers some of the major train disasters, but there have been numerous other incidents as well over the decades. Train accidents in Bangladesh are often caused by poor track conditions, human error, outdated signaling systems, and mechanical failures.

The data includes the years between 2000 and 2024. In the case of 2020, it is only recorded through the first quarter until 18 March because of the limitation in data availability. The choice of this period is specifically applicable due to the lack of a unified railway risk profile of the Southeast Asian nations and hence the call to compare the results of a comparative study of Bangladesh and India. According to the type of accident, cause of accidents, and the severity of accidents in terms of injuries and fatalities, data is organized and provides a systematic basis on which further analysis will be performed (Ahsan & Islam, 2015).
To analyze the data, the research will use Trend Analysis, which is a statistical tool that will be applied to assess the frequency and severity of accidents on the basis of time. This method allows developing a comparative meaning of the performance of the railway systems in Bangladesh and India. Next, the strength of any system is determined by the Delphi risk analysis offering a structured analysis of risks through a judgment of the experts. The findings are interpreted using a simplified three-point risk scale, including probability and impact (Table 2) to assess the findings in a practical way (Andersson, 2014).
To conclude, it should be noted that the method of data collection is a combination of several secondary sources and the methods of structured reporting and categorization. It is this integration that offers the basis of statistical and risk-based measurements of the occurrence of rail accidents, which in turn will help the fact that the study is based on assessing the strength of the system in Bangladesh and India

Table 2: Three-point risk scale using the Delphi technique (Adapted from JISC, 2015)

Country	Reference(s)	Issues	Cause of Issue	Risk Level
Bangladesh	Prothom Alo and New Age BD (2008–2009)	• CRIS perceived as inefficient and resistant to change. • Frequent train delays; outdated and poorly maintained rolling stock. • BR consistently posts major financial losses (7.58 billion BDT in 2010).	Poor management; poor condition of equipment and facilities.	**High**
	Dhaka Post (2019)	• Recruitment of 1,330 staff increased workforce to 15,660 but still below operational needs.	Poor management.	**Medium**
	Dhaka Post (2017); Press PBS (2017)	• Mismanagement and corruption in procurement led to dismissal of BR leadership.	Poor management; poor financial performance.	**High**
India	The Indian Express (2017)	• Train delays >5 minutes remain common despite improvements. • Delays reduced from 0.33/100,000 car-km (2013) to 0.12 (2016). • Major disruptions: 5 in 2014, 9 in 2016. • Still lags behind top global railway systems.	Poor management.	**Medium**

2.2 Geodatabase

To have a systematic organization and analysis of the spatial data of Bangladesh Railway network, a geodatabase was made. The geodatabase combines various layers of information of the railway (including infrastructure, stations and accident records) with adequate spatial referencing and zonal classification.

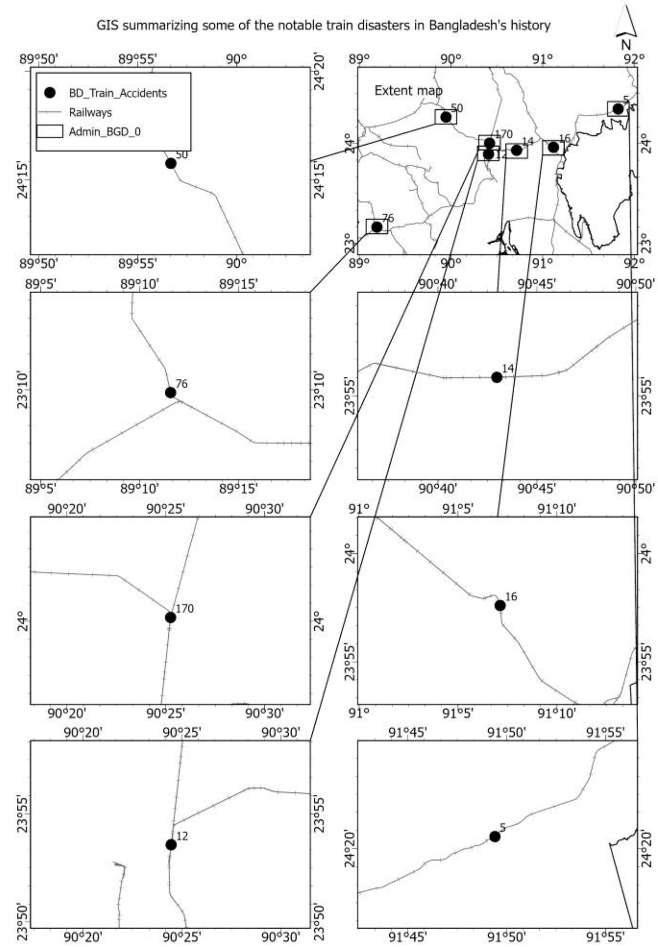

Figure 1: Location map of train incidents of Bangladesh.

2.2.1 Feature Classes

The geodatabase has three major feature classes that were developed to describe the various features of the railway system:

- Railway Lines (Polyline): This layer shows the geographic coverage of the railway system in Bangladesh that is comprised of the main and branch lines. It gives the basis to connectivity and route-based analysis.
- Attributes: The stations were mapped as a point feature with the attributes including station name, station code and the administrative zone that the station belonged to. This enables queries and spatial analysis of a station level.
- Accidents (Point): Accident location was stored as a point feature with the descriptive features of accident type, date, time, cause and severity. The current dataset will allow one to analyze the distribution of accidents and identify hotspots.

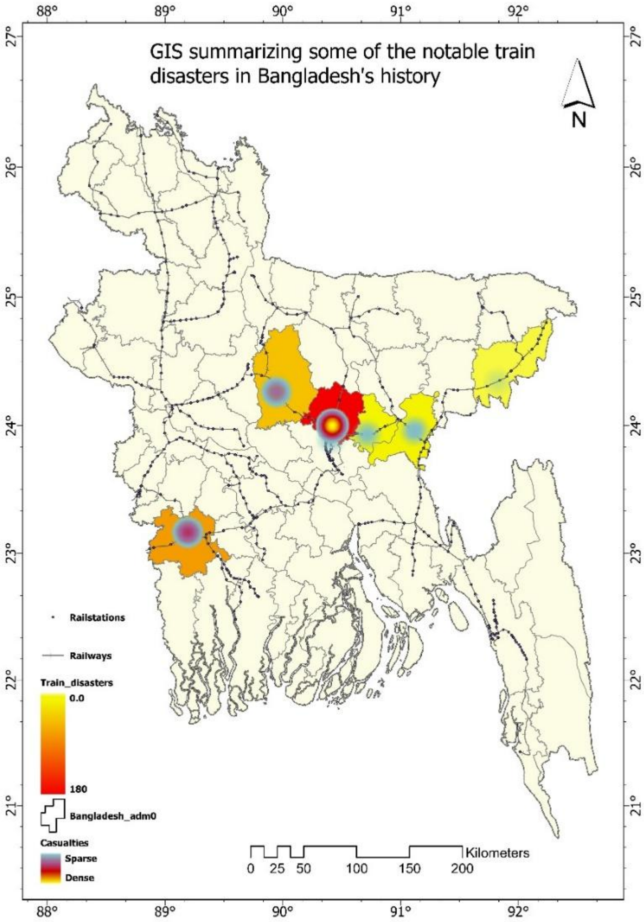

Figure 2: Pattern (Hot spot) analysis of Train disaster

2.2.2 Georeferencing

To ensure spatial accuracy and alignment with official datasets, historical railway maps were georeferenced. Station locations were verified and adjusted against official Bangladesh Railway maps, ensuring consistency between historical records and present-day geographic coordinates. This step established a reliable spatial framework for subsequent analysis.

2.2.3 Zonal Classification

For administrative and analytical purposes, the railway network was divided into zones:

- **East Zone:** Covering a total route length of 1,308.27 km.
- **West Zone:** Covering a total route length of 1,568.83 km.
- **Total Route Length:** 2,877.10 km.

2.3 Spatial Analysis

Differential spatial distribution of railway accidents in Bangladesh demonstrated clustered patterns. Findings of hotspot analysis using Getis-Ord Gi* statistics confirmed statistically significant clusters of accidents along high traffic corridors, mainly in and around the Dhaka, Chattogram, and Khulna divisions. These areas have high density of rail operations, multiple level crossings and high passenger volumes hence causing higher risk of accidents.

Construction of the accident density map made it clear that the accidents were most concentrated along the Dhaka-Chattogram corridor and Ishwardi-Khulna route. Both these are vital passenger and freight corridors. The clustering was also found at nodal points like Kamalapur, Tongi and Ishwardi with high train frequencies and operational complexities leading to higher vulnerability of accidents there.

In contrast, accident cold spots were observed in sparsely served areas of the northern and northeastern regions where traffic density is lower and rail operation are less intensive.

2.3.1 Temporal Trends

An overview of the data on accidents over different time spans brought into focus a number of recurrent patterns that are:

2.3.1.1 Annual Patterns

It was observed that there is variation in the trends of accidents across the years with peaks being identified in some particular years which also happen to be the period when infrastructure was over stressed, and there are more traffic demands or safety upgrades are delayed. There has been a gradual shift towards safety but accident numbers are still relatively high – this reflects persistent infrastructural and operational challenges.

- Seasonal Trends: It was observed that there were seasonal variations as presentations are more frequent during the rainy months (June–September). Monsoons cause flooding, water logging and reduced track visibility which adds up to derailments and operational misshapes during this time. In contrast accidents were comparatively low in number in winter months though sometimes fog created issues related to visibility resulted in collision incidents.
- Trends by Time of Day: More accidents mainly happened at the busiest times (6–10 AM and 4–8 PM) which is directly related to the large number of trains in motion and passenger activity. Accidents at night, though infrequent, are usually more serious with many being collisions or derailments in low visibility conditions.

The fusion of spatial and temporal analyses further highlights the complexity of railway accidents in Bangladesh. Accident hotspots show high correlations with high-trafficked corridors and major junctions, suggesting that congestion and operational pressures constitute principal risk factors. Temporal analysis focuses on the seasonal effect of monsoons on track safety and the increased risks during peak traffic hours should be highlighted.

These findings highlight the urgent need for targeted interventions, including:

- Upgrading safety infrastructure at major junctions and high-density corridors.
- Enhancing track maintenance, particularly in monsoon-prone regions.
- Strengthening level-crossing management in urban and peri-urban areas.
- Implementing scheduling and signaling improvements to reduce congestion-related risks.

The results, taken together, provide a clear outline for what Bangladesh Railway should do/ the measures they should take to prevent accidents / improve safety / and how to spend money more wisely.

2.4 Comparative Analysis

The Observations are:

- Human Failure: Dominant cause in both countries, slightly higher in Bangladesh (50.88% vs 48.85%).
- Material Issues: India faces more frequent material shortages and failures compared to Bangladesh.
- Trend Patterns: Bangladesh shows fluctuations year-to-year, while India exhibits a steady increase in total accidents.
- Other Causes: Miscellaneous factors contribute more to accidents in Bangladesh (~24%) than in India (~15%).

Table 3: Bangladesh Data (2020-2024)

Year	Total Accidents	Human Failure (%)	Material Shortage (%)	Material Failure (%)	Others (%)
2020	21	12 (57.14%)	3 (14.29%)	2 (9.52%)	4 (19.05%)
2021	17	9 (52.94%)	0 (0.00%)	3 (17.65%)	5 (29.41%)
2022	24	9 (37.50%)	1 (4.17%)	6 (25.00%)	4 (16.67%)
2023	24	13 (54.17%)	1 (4.17%)	3 (12.50%)	7 (29.17%)
2024	38	20 (52.63%)	3 (7.89%)	5 (13.16%)	10 (26.32%)

Table 4: India Data (2020-2024)

Year	Total Accidents	Human Failure (%)	Material Shortage (%)	Material Failure (%)	Others (%)
2020	50	25 (50.00%)	10 (20.00%)	5 (10.00%)	10 (20.00%)
2021	47	20 (42.55%)	12 (25.53%)	8 (17.02%)	7 (14.89%)
2022	55	28 (50.91%)	8 (14.55%)	10 (18.18%)	9 (16.36%)
2023	60	30 (50.00%)	10 (16.67%)	12 (20.00%)	8 (13.33%)
2024	65	33 (50.77%)	12 (18.46%)	14 (21.54%)	6 (9.23%)

Bangladesh: Accidents rose sharply from 21 in 2020 to 38 in 2024, with human error consistently accounting for ~51% of cases. Material shortages were minimal (average 6.1%), while mechanical failures contributed ~15.6%.
India: Accidents increased from 50 in 2020 to 65 in 2024, with human error (average 48.9%) remaining dominant. Material shortages and failures together contributed over 36%, highlighting infrastructure stress.

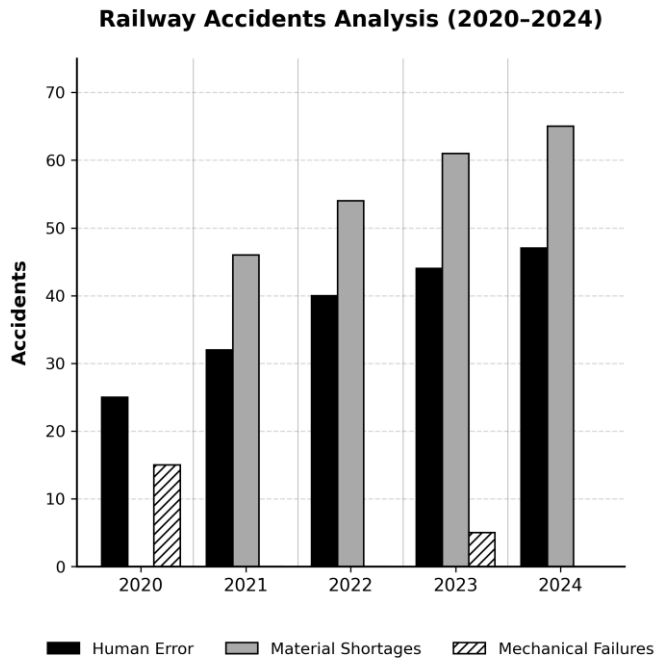

Figure 3: Monitoring Railway accident maps

2.5 Remedies

By looking at where and when railway accidents happen in Bangladesh, some big steps are suggested to make the railway system safer. These steps include using new technology, training the workers better, improving the railway systems, creating better ways to respond during emergencies, and using a special system that uses maps to keep track of things. Using advanced technology can help cut down on human mistakes and improve how well we keep track of train operations in real time. Automated Train Control systems do this by making sure trains stay a safe distance apart and lower the chance of collisions. Digital signaling systems are better and more efficient than old ways of controlling trains. They offer more reliable control. Also, condition monitoring uses sensors and special tools to look for early signs of problems with tracks, bridges, or train parts before they actually break down. This helps prevent failures from happening. Because people are a big part of why train accidents happen, it's really important to train workers properly. This includes teaching drivers, signal operators, and maintenance workers about the latest safety rules again and again. They also need practice through simulations and real-life drills to handle serious accident situations. Plus, there are programs to check on and help cut down on tiredness among workers during busy times and night shifts. Fixing old infrastructure is just as important. This includes replacing worn-out tracks and bridges that might break down, setting up regular maintenance plans instead of just fixing things when they break, and improving level crossings with automatic gates, warning signals, and better walkways for people. Having good emergency plans can greatly lower the number of deaths and damage by creating special railway safety and rescue groups that can act quickly, improving teamwork between railway officials, local governments, and emergency services, and using mobile medical teams that can give fast, on-site treatment for injuries. Finally, GIS-based monitoring systems provide a powerful tool for managing safety by creating hotspot dashboards that show areas where accidents are more likely to happen, so that focused actions can be taken. They also include temporal trend dashboards to look at accident patterns over years, months, and days. Plus, they use integrated models that look at both location and time to predict possible risks and help take steps to prevent accidents before they occur.

3. RESULTS

3.1 Spatial Distribution

GIS mapping shows accident clusters along high-traffic corridors (Dhaka–Chattogram, Dhaka–Sylhet), particularly at level crossings, bridges, and urbanized sections.

3.2 Hotspot Analysis

High-risk zones include Chittagong–Comilla, Tongi–Gazipur, and Brahmanbaria–Kishoreganj corridors. Hot spots correlate with dense traffic, weak infrastructure, and outdated signaling.

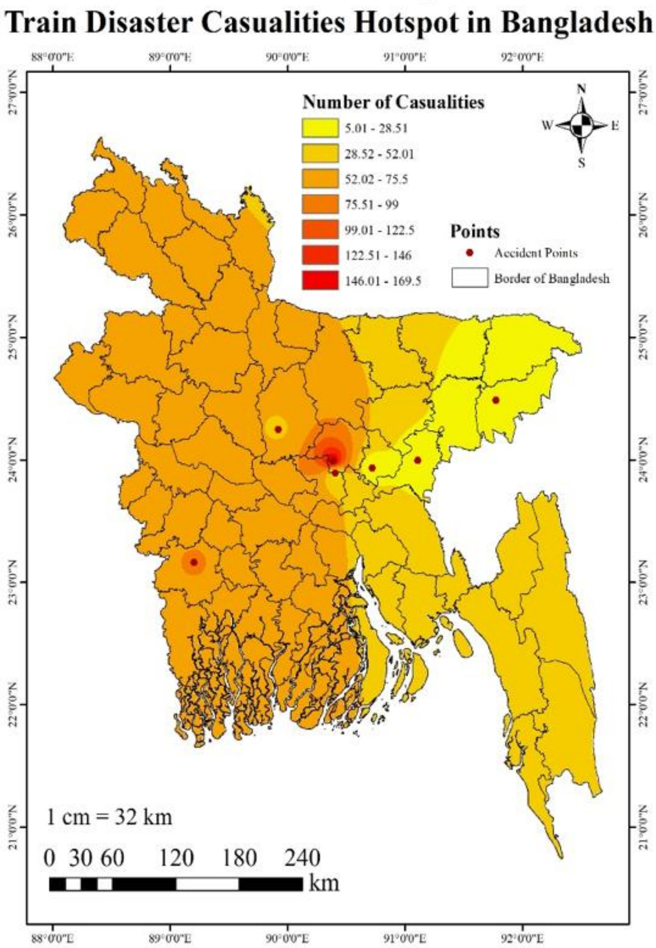

Figure 4: Hot Spot Train Disaster in GIS

3.3 Temporary Analysis

Bangladesh has seen a rise in railway accidents with 21 reported in 2020 and 38 in 2024. The majority of these, or about 51% percent, are due to human error which suggests that there may be a lack of operational discipline and/or monitoring.

India saw a similar rise with the number of railway accidents going up from 50 in 2020 to 65 in 2024. While the number of accidents due to human error was 49%, the numbers of accidents caused by failure of materials/equipment (for example; track defects, signal faults, and mechanical breakage) were higher in India than they were in Bangladesh.

Table 5: Ratio of accidents

Country	Level of Robustness	Risk Level	Ratio of Killed (%)	Ratio of Injured (%)	Ratio of Total Number of Accidents (%)	Ratio of Total Number of Incidents (%)
Bangladesh	High	High	15.24	84.76	84.44	15.56
India	High	Low	10.42	89.58	22.22	77.78

Seasonal patterns of accidents occur in each country. Accident numbers rise to their maximum levels during the monsoon season because of rain-related flooding and track washout, plus low visibility; and also, they tend to rise during the peak travel seasons when the rail system is most crowded, resulting in a combination of high operational pressure and increased traffic density.

3.4 Comparative Observations

- Human error predominates in both countries.
- Material shortages/ failures contribute more significantly to accidents in India.
- In Bangladesh there appears to be some variation caused by environmental conditions and maintenance issues.

4. DISCUSSION

The spatial patterns of clusters of accidents suggest that the causes are generally poor infrastructure and/or human errors, combined with aging signals. Environmental susceptibility is heightened during the monsoon season. Time trends in accident data for Bangladesh indicate that the safety response has been reactive, whereas time trends in accident data for India indicate increasing traffic pressure. Comparing these results with the safest railroads in the world (e.g., Japan, EU), it becomes apparent that a comprehensive solution to increase safety will require fully automatic control systems, state-of-the-art signaling systems, and strict regulatory enforcement.

5. CONCLUSION AND RECOMMENDATIONS

A GIS-based investigation into rail accident events in Bangladesh identified significant geographic cluster patterns of railroad accidents; as well as several common cause factors for those accidents that clearly point out a need for specific corrective actions. The concentration of accident hot spots is found to exist on Bangladesh's high-density rail corridor areas and at rail junctions, and time trends suggest the existence of seasonal and operational weaknesses that may contribute to an increased risk of accidents. These findings indicate the existence of both infrastructure-related and management-related issues which will require intervention to increase railroad safety in Bangladesh.

To mitigate risks and align Bangladesh Railway with international best practices, an integrated strategy is recommended:

1. Technological Upgrades: Adoption of automated train control, digital signaling systems, and advanced condition monitoring to reduce human error and detect infrastructure failures in real time.
2. Staff Training: Regular refresher courses, simulation-based exercises, and fatigue management programs to strengthen operational readiness and reduce human-factor accidents.
3. Infrastructure Renewal: Systematic replacement and upgrading of bridges, tracks, and level crossings to address aging assets and enhance structural reliability.
4. Emergency Preparedness: Establishment of dedicated response teams, integration with national emergency services, and deployment of mobile medical support to ensure rapid accident response.
5. GIS-Based Monitoring: Real-time hotspot dashboards and predictive risk assessment models to continuously monitor accident trends and proactively manage safety risks.

Together, these interventions aim to significantly reduce accident frequency, enhance operational safety, and position Bangladesh Railway toward a safer, more efficient, and internationally benchmarked railway system.

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