Analysis of Hazards, Risk and Safety Environment in Railways with reference to Dedicated Freight Corridor Corporation of India Limited

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Abstract— Dedicated Freight Corridor Corporation of India Ltd. (DFCCIL) has been given a mandate to construct, maintain and operate Dedicated Rail Freight Corridors across the country. To begin with, the Government of India has entrusted DFCCIL with construction, maintenance and operation of Eastern Corridor between Sanehwal near Ludhiana to Dankuni in West Bengal and Western Corridor connecting Dadri in Uttar Pradesh to Jawaharlal Nehru Port (JNPT) in Mumbai. The Corporate Plan, to the construction of DFCs, is a “work-in-progress”. DFCCIL undertakes the challenge of building one of the largest rail transport infrastructure initiatives post-independence. The primary objective of this study is to provide an improved method for rail safety appraisal at “railway-highway” grade crossings through the development and application of suitable safety risk scores (called ‘Safety Risk Index’) with a combination of both accident frequency and accidental consequences prediction models generated for crossings, and also by using these safety risk scores to identify the worst or most dangerous locations.

Keywords: DFCCIL, Hazard Analysis, Risk Matrix, Safety Manuals, Railway Accidents, Safety Risk Index, PPEs, and Practical Approaches

I. INTRODUCTION

The study in this thesis was conducted to analyze the causes, impacts and management of disasters in Indian Railway. In order to fulfill the objectives of the study, the secondary data with respect to number of railway accidents, losses, deaths, injuries, the causes of railway accidents etc. for last few years was obtained, compiled and statistically analyzed. The disaster management system in Indian Railway was studied with respect to railway disasters.

Railway Disaster at national, zonal and divisional level which provides the framework for prevention, mitigation, preparedness, rescue, relief and rehabilitation through risk identification, hazard mapping, preventive and ant sabotage security system, crowd management plans, 'Golden Hour' response, hospital disaster plan, training, technology up gradation, periodic mock drills etc. The results revealed that there are four major categories of accidents viz. derailment, level crossing accidents, collisions and fire in trains which are caused by three major factors viz. human error, equipment failure, and sabotage.

Railway Disaster is a serious train accident or an untoward event of grave nature, either on railway premises or arising out of railway activity, due to natural or man-made causes, that may lead to loss of many lives and/or grievous injuries to a large number of people, and/or severe disruption of traffic etc, necessitating large scale help from other Government/Non-government and Private Organizations [1] infrastructure and property destruction. The associated economic and environmental costs can be devastating but it can be contained if the management systems in place to plan for, respond to or recover from them fail [2].

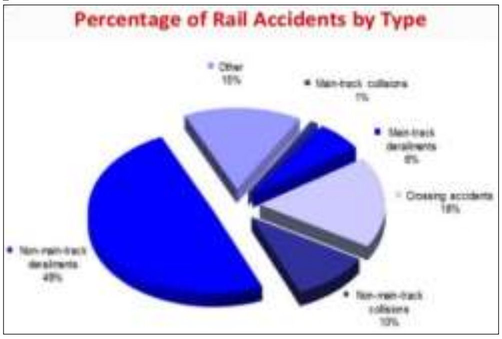

Fig. 1: Indian Rail Accident Scenarios [3]

Fig. 2: Main Cause of Rail Accident in India [7]

This chapter introduces the research topic and briefly discusses the initiative of the Research in Dedicated Freight Corridor Corporation of India Limited (DFCCIL). It briefly presents an outline structure of the thesis and explains the reasons why this study is of interest. The aim of the study is also highlighted and a brief description of the developing concept of a risk assessment model (Safety Risk Index) is discussed. It initially provides the basic definition of safety and risks and briefly describes Occupational Health and Safety (OHS) in railway industries. It provides an overview of general safety management systems used in railway industries. In addition, it elaborates the background of the existing potential of rail safety risks and the overview of rail safety management systems. It also describes the objectives of the research study and lists the benefits achieved in relation to this research. Finally it outlines the structure of the thesis in detail.

1) Overview of hazards, risk and safety in railway
2) Safety management system (SAM)
3) Safety master plan of DFCCIL
4) Safety analysis procedure

II. LITERATURE REVIEW

G Raghuram et.al [17] Indian Railways has been one of the drivers of the fast-growing Indian economy. Dedicated Freight Corridors (DFCs) were planned along the Golden Quadrilateral rail route to further this growth.

Sobhesh Kumar Agarwalla et.al [18] a new large railway project offers opportunity for structuring in a manner that best value can be delivered towards transportation. This is more so in the context of an existing large integrated railway system (Indian Railways (IR)) directly under the Government.

Bodhibrata Nag et.al [19] a large number of railway mega-projects are planned or are under implementation for capacity augmentation, for serving the needs of trade, specific regions or industry sectors. Since transport capacity is one of the main levers of economic progress, it is essential that augmentation of transport capacity is not held up.

Jelena M. Andric et.al [20] The Belt and Road Initiative (BRI) is a Chinese development strategy developed in order to establish connectivity and deepen cooperation between China and other countries, increase trade, and support the socio-economic development of vast regions.

Qi Zhang et.al [21] In order to make safety risk assessment more accurately and more reasonably for high-speed railway station in China, this paper analyzes risk factors of fault tree and transfers the fault tree of risk accident into fuzzy petri net and then builds the FPN-FTA model by combining the dynamic weighting fuzzy petri net (FPN) and fault tree analysis (FTA) based on the latter. .is paper simulates the FTA-FPN model with State flow of Matlab software. .en, it builds up a bi-objective risk control model, making the minimum safety risk level and minimum necessary cost as the objectives, and it designs discrete particle swarm optimization algorithm to solve the risk control model.

Mrunal Patil et.al [22] Risk management is an important concept that mainly aims at identifying, quantifying, mitigating and reviewing of events that may have an adverse impact on the organization.

III. Company Domain

The Indian Railways' quadrilateral connecting the four metropolitan urban communities of Delhi, Mumbai, Chennai and Howrah, generally known as the Golden Quadrilateral; and its two diagonals (Delhi-Chennai and Mumbai-Howrah), signifying a complete course length of 10,122 km including 16% of the course conveyed over 52% of the traveler traffic and 58% of income winning cargo traffic of IR. The current trunk courses of Howrah-Delhi on the Eastern Corridor and Mumbai-Delhi on the Western Corridor were profoundly immersed, line limit usage changing between 115% to 150%.

Dedicated Freight Corridor (DFC) is a rail course made for cargo (products and item) transportation. Worked as per world-class innovation, DFC guarantees quicker travel, diminished coordination costs, higher vitality effectiveness and condition inviting tasks. Cargo transportation assumes a tremendous job in the Indian economy. Thinking about its mammoth commitment of 67 percent in railroad income, the legislature has chosen to incorporate best in class innovation and up-scale the rail route framework by means of Dedicated Freight Corridors (DFC).

The change won't just modernize rail framework however will likewise improve the cargo limit, along these lines diminishing the general expenses. By definition, Dedicated Freight Corridor (DFC) is a rapid and high-limit railroad hallway devoted solely for cargo development. It is worked to avow a higher throughput for each train and an increasingly critical offer in the cargo showcase. Additionally, a world-class foundation, DFC likewise guarantees:

- High vitality effectiveness
- Reduced unit expense
- Faster travel
- Employment
- Real domain extension

Environment-accommodating activities

Fig. 3: Eastern Dedicated Freight Corridors [30]

Fig. 4: Western Dedicated Freight Corridors [30]

IV. Problem Formulation

Indian Railways (IR) has been growing rapidly in the past 18 to 19 years in comparison to its growth measured from a base year of 1951. The route kilometrage from 1951 to 2006 had increased from 53596km in 1951 to 62367km in 1991 and to 63332km in 2005. This represents an increase in kilometrage of 16.36% in 1990-91 and 18.16% up to 2005-06. It is significant that although from 1990-91 to 2005-06 the increase in route kilometrage has been only 965km representing an increase of 1.55%, the corresponding freight traffic carried has witnessed an increase from 341.4 million tonne in 1991 to 682.4 million tonne in 2005-06 an increase in volume that has more than doubled in this 15 years. Similarly, passenger traffic has grown from 66.5 billion passenger km in 1950-51 to 295.64 billion passenger km in 1990 - 91 and 615.63 billion passenger km in 2005-06 representing a growth of 4.45 times and 9.26 times respectively.

The passenger traffic has also doubled during the period 1990-91 to 2005 - 06. Current trends of both freight and passenger traffic are maintaining the same growth profile.

- Accidents
- Hazards
- Risk
- Safety
- $\text{Risk} = \text{Probanility of an accident} \times \text{Losses Per Accidents}$

Priority Rail Safety Issues	
1. System Based Safety Issues	2. People Based Safety Issues
• Signal Passed at Danger (SPAD)	• Driver Alertness
• Automatic Train Protection (ATP)	• Drugs and Alcohol
• Lack of Co-operation at Global Level	• Job Training
• Comprehensive Rail Safety Information	• Effective Communication
• Safe Team Work in Various Railway Operations	• Train Boarding and Alighting
• Privatisation of Railways	• Employees Working on or about the Track
• Formal Safety Operational Recognition	• Dangerous Goods
• Independent Bodies for Accident Investigations	• Level Crossings / Track Invaders

Table 1: Priority Rail Safety Issues [40]

A. In General Safety Issues: -

1) Signal passed at danger (SPAD)
2) Automatic train protection (ATP)
3) Lack of co-operation at global level
4) Availability of comprehensive information on rail safety
5) Safe team work between various railway operations
6) Privatization of railways

B. People Based Safety Issues: -

1) Driver alertness
2) Drugs and alcohol
3) Effective communication
4) Job training
5) Train boarding and alighting
6) Employees working on or about the track
7) Dangerous goods
8) Track invaders
9) Level crossings

V. METHODOLOGY

To develop the railway risk assessment models, various risk management procedures were reviewed such as ISO/IEC Guide [45] and the risk management procedure applied to this study was developed. It is similar to the common approach risk management suggested in data set. The scheme shows three dimensions: a railway system, the life cycle of this system and the process of risk management.

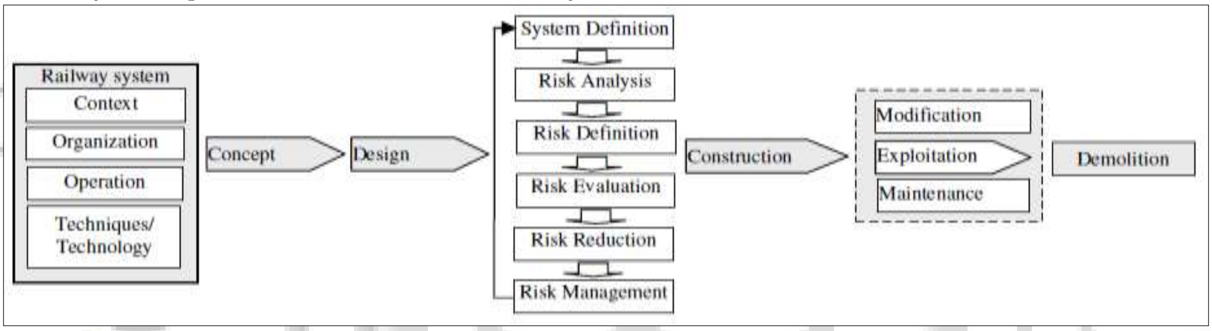

Fig. 5: Common Approach of Risk Management [45]

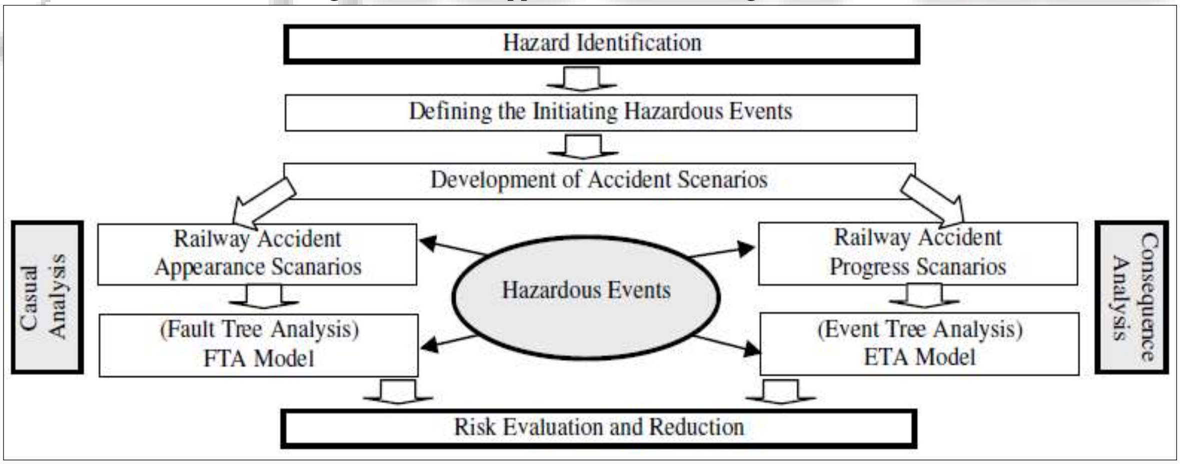

Fig. 6: Railway Risk Assessments General Procedure [48]

To perform hazard identification, it is required to understand what consist of hazards, how to recognize it and how to define it [49]. That is, the understandings of accident appearance and progress sequences are needed. The following procedure was used in hazard identification stage and the railway accident scenarios were developed to define these sequences:

1) System definition, boundary: setting up objective of hazard identification and its boundary.
2) Identifying hazardous events, hazards and barriers: Including the definition of measures which stops the increases of accident.
3) Developing accident appearance scenarios: defining relationships among hazardous events, hazards and barriers.
4) Developing accident progress scenarios: considering the relevant key influential factors.
5) Accident scenario management: drawing up hazard log.

A. Development and Management of Rail Safety

Safety rules and standards, such as operating rules, signaling rules, requirements on staff and technical requirements applicable to rolling stock, have been devised both nationally and internationally. Under the regulations currently in force, a variety of bodies deal with safety. These national safety rules, which are often based on national technical standards, should gradually be replaced by rules based on common international standards, established by technical specifications for interoperability.

The new national rules should be in line with current legislations and facilitate migration towards a common approach to railway safety. In this connection, the Rail sector ensures that:

1) Railway safety is generally maintained and continuously improved, taking into consideration the development of current legislations;
2) Safety rules are laid down, applied and enforced in an open and nondiscriminatory manner;
3) Responsibility for the safe operation of the railway system and the control of risks associated with it is borne by the infrastructure managers and railway undertakings;
4) Information is collected on common safety indicators through annual reports in order to assess the achievement of the common safety targets and monitor the general development of railway safety.

In order to coordinate the different rules, a distinction needs to be drawn between:

1) Infrastructure managers, who are bodies or companies responsible in particular for establishing, building and maintaining infrastructure and safety;
2) Railway undertakings, which are private sector service providers and government agencies engaged in the supply of goods and/or passenger transport services by rail.

B. Key Components of SMS Managed by Rail Sectors

The railway is committed to maintaining a high degree of safety awareness and continuously employing management systems to strive for continuous improvement in safety performance. A risk-based approach is generally adopted for managing safety internally by Rail sectors. The SMS provides a workable framework for managing safety in a systematic, proactive and consistent manner, so that the Safety Policy can be effectively implemented. It allows the railway to manage safety systematically, similar to how other critical aspects of the business are managed, and reduces the need for "safety experts" as safety management then becomes line management's responsibility. Most importantly, all staff involved can discuss safety using the same language.

DFCCIL stated that the Rail SMS comprises the following nine key components:

Safety Policy: -

1) Setting high standards which consistently meet legal requirements;
2) Giving specific safety responsibilities to individual;
3) Training up staff and manage contractors to ensure safety in their activities;
4) Maintaining safety communication channels at all levels;
5) Employing management systems that will reduce risks to as low as reasonably practicable;
6) Measuring safety performance by identifying appropriate indicators;
7) Using internationally recognized modern practices and processes; and
8) Providing necessary funding and resources.

Safety Tasks: -

1) Task 1: Safety Information
2) Task 2: Safe Systems of Work
3) Task 3: Asset, Design and Project Management
4) Task 4: Protective Equipment
5) Task 5: Fire
6) Task 6: Human Resources
7) Task 7: Communication on Safety Matters
8) Task 8: Contractors and Visitors
9) Task 9: Emergency Preparedness and Response
10) Task 10: Accident Reporting and Investigation
11) Task 11: Safety Inspections
12) Task 12: Safety Performance Monitoring
13) Task 13: Funding for Safety
14) Task 14: Review and Audit
15) Task 15: Security

Safety Management Process: -

1) Policy
2) Organizing
3) Planning
4) Implementing
5) Monitoring
6) Review
7) Audit

Safety Responsibility Statements: -

Safety Audit System: -

1) System audit
2) Activity audit
3) Contractor audit and
4) Safety technical audit.

Risk Control System: -

Safety Critical Items: -

Safety Committees: -

Staff Consultation: -

VI. CALCULATION AND RESULTS

The previous chapter overviewed the current safety issues in the Rail sectors and the safety management systems in place. It also identified the major safety issues and the significance on improving the safety at level crossings. In order to address those safety issues identified through a risk assessment model and its applications are applied in the past chapter, the research methodology adopts here performed by using many different strategies used in DFCCIL industry. The initial step in the process of improving the safety is to develop a theoretical framework on safety risk evaluation at rail grade crossings. This is followed by developing a risk assessment model, based on the risk factors influencing accidents at grade crossings.

Risk Analysis consists of the estimation of the frequency of the accidental events and their respective consequences. The frequency of the accidental events may be estimated based on historical data of previous incidents, fault tree analysis or expert judgment. The consequence analysis identifies both immediate consequences and those that are not apparent until sometime after the accidental event. All potential event chains following an accidental event must be identified and described. Consequence analysis may be conducted using event tree analysis, simulations or can be derived from historical data. Cause-consequence analysis is another technique for consequence analysis which explores system responses to an initiating "challenge" and enables assessment of the probabilities of unfavorable outcomes at each of a number of mutually exclusive loss levels.

Selecting appropriate method for risk analysis varies, depending on the nature of risk, the purpose of the analysis, and the required protection level of the relevant information, data and resources. It is essential to match the risk assessment method to the objective of the risk analysis and expected deliverables. It is very important to note that the quality of risk assessment deliverables is greatly influenced by selecting the appropriate method to review the system or issue identified.

– Qualitative
– Quantitative
– Semi-Quantitative

Identifier	Descriptor
Very likely	Very common event or very likely to occur (p > 0.1)*
Likely	Probably will occur or "it has happened" (0.1 > p > 0.01)
Possible	May occur or "heard of it happening" (0.01 > p > 0.001)
Unlikely	Not likely to occur or "never heard of it" (0.001 > p > 0.000001)
Highly unlikely	Practically impossible (0.000001 > p)

Table 2: Group Selection for Estimating Probability of an Event DFCCIL

Identifier	Descriptor
Fatality	Catastrophic or fatal event
Major injury	Critical serious injury yields permanent disability
Minor injury	Moderate or average lost time injury occurs
First aid only	First aid given to minor injury
Negligible	No injury at all

Table 3: Group Selection for Measuring Consequences of an Event DFCCIL

As such, it generally can be considered a rough method of risk analysis that simply divides the identified risks into four categories:

– Extreme
– High
– Medium or Moderate
– Low

Some techniques outlined below are suitable for categorizing risks on the basis of individual or team opinion. Further, differences between categories (high, medium, low, etc.) are difficult to define and quantify as they simply describe using qualitative terms.

Likelihood (Probability)	Consequences (Severity)				
	Negligible	First aid only	Minor injury	Major injury	Fatality
Very likely	M	H	H	E	E
Likely	M	M	H	H	E
Possible	L	M	M	H	H
Unlikely	L	L	M	M	H
Highly unlikely	L	L	L	M	M

Identifier	Risk Level	Risk Control Measures
E	Extreme risk	• Activity must not start or if started, must be stopped; • Immediate action required; • Notify supervisor or appropriate Health and Safety Authority as required; • Highest level corporate management needs to be involved; • Identify hazards and implement controls to reduce risk to low before starting or recommencing activity.
H	High risk	• Activity must not start or if started, must be stopped; • Immediate action required; • Notify supervisor as required; • Senior site management needs to be involved; • Identify hazards and implement controls to reduce risk to low before starting or recommencing activity.
M	Moderate risk	• Immediate action to minimise injury e.g. signs; • Supervisor remedial action required within 5 working days; • Complete risk assessment needed; • Identify hazards and implement controls to reduce risks; • Management responsibility must be defined.
L	Low risk	• Remedial action within 1 month, supervisor attention required; • Identify hazards and implement controls as required; • Manage by routine processes.

Table 4: A Typical Qualitative Risks Ranking Matrix at DFCCIL

Smoking	0.05	or	1 in 200
Mining Accidents	0.001	or	1 in 1000
Road Traffic Accidents	0.0001	or	1 in 10000
Industrial Accidents	0.00001	or	1 in 100000
Flying in Commercial Aircraft	0.00001	or	1 in 100000
Fire / Explosion at Home	0.000001	or	1 in 1 million
Lightning	0.0000001	or	1 in 10 million

Table 5: Probability of Death in India

In order to provide rail safety evaluation from a quantitative perspective, the fundamental elements associated with risk measurement need to be initially identified. Based on research activities conducted by various researchers on quantitative safety risk modeling techniques, three basic elements are identified. These three elements are:

1) Exposure (E) - Measurement of exposure of rail users (employees, passengers and the public) to potential railway hazards.
2) Probability (P) - Measurement of the chance of rail users being involved in potential railway accidents.
3) Consequence (C) - Measurement of the severity level to rail users resulting from potential railway accidents.

Given safety risk assessment varies with the location of particular railway infrastructure and the specific hazard, the index SRI (i^{th} $_{\text{Specific Hazards}}$) defines the risk associated with the specific hazard (i^{th}) and is derived by combining risk scores of three basic elements of the hazard described above. The risk scores are the estimated values, which are derived from predicted values of three basic elements using mathematical models. The SRI for a specific hazard (i^{th}) can be defined as:

$$SRI_{(i_{th} \text{Specific Hazards})} = E_i \times P_i \times C_i$$

Where,
E_i - the risk score due to exposure for i_{th} hazard
P_i - the risk score due to probability for i_{th} hazard
C_i - the risk score due to consequence for i_{th} hazard

The overall risk index All Hazards SRI defines the combination of risks associated with all hazards within the location concerned. Hence, the SRI for combination of all hazards at the location can be calculated using:

$$SRI_{\text{All Functions}} = \sum_{i=1}^{n} E_i \times P_i \times C_i$$

Where, n - total number of hazards within the location concerned

It can obviously be noted that

$$\frac{SRI_{(Crossing\ 2)}}{SRI_{(Crossing\ 1)}} > 1$$

$$SRI_{(Crossing\ 2)} > SRI_{(Crossing\ 1)}$$

Based on this illustration and overall safety evaluation using risk index values of all three basic elements (exposure, probability and consequences), it may be concluded that: -

Crossing - 2 has higher risk potential than Crossing - 1 in relation to the hazard of collisions and their consequences.

Risk No.	Risk Definition	IRR (I×P)	Level of Risk (Severity)
1	Delay in design submission	625	Critical
2	Inefficient Land Acquisition Management System	500	Critical
3	Inadequate staffing	500	Critical
4	Design Failure	500	Critical
5	Fault in ERP-SAP system	500	Critical
6	Ineffective handling of ERP-SAP system	500	Critical
7	Delay in Implementation of PMS module of SAP	500	Critical
8	Cash constraint with the contractors for execution of works	500	Critical
9	Delay/ difficulty in construction of RUBs/ROBs (Issues pertaining to construction of RUBs/ ROBs)	400	Critical
10	Disaster management	400	Critical
11	Resource planning	400	Critical
12	Arbitration cases/ Award of land	400	Critical
13	Accidents and Mishaps at construction sites	400	Critical
14	Delay in finalization of PPP Process	400	Critical
15	Inadequate management of contractor	400	Critical
16	Problem of Office Management	375	Critical
17	Distortion/ non-accuracy of Employee data.	375	Critical
18	Grievance Redressed Mechanism	375	Critical
19	Increased cost/ budget overrun in DFCCIL	300	Critical
20	Problems in matching of IR assets at junction and relocating of IR assets	300	Critical

Table 6: top 20 risks: Planning & Construction and Operation Stage of DFCCIL for 2020 – 2021

VII. CONCLUSION

This chapter provides a brief summary of research contributions and conclusions made along with research findings reported earlier. The aim of this research is to provide a strong basis for the initial process of safety improvement at railway highway grade crossings. The research work carried out and reported in this thesis is considered to be an integral part of a comprehensive international multi-stage safety management program, which generally consists of five interconnected initiatives:

1) Separate models for prediction of accidents and consequences at grade crossings were developed
2) Grade crossings, where the potential risk of accidents is unacceptably high, were identified
3) Grade crossings, where the potential risk of consequences is unacceptably high, were identified
4) A single composite index (Safety Risk Index), using the prediction of accidents and consequences to assess and priorities the risk potential at the crossings, was developed.
5) With the estimated values of the Safety Risk Index, all ‘Black-spot ‘crossings, where the overall potential risk is unacceptably high, were identified.

These five initiatives carried out as part of this research are discussed in detail and the conclusions associated with each initiative are summarized in this chapter. These initiatives assist in the development of comprehensive safety intervention programs at state and national levels that includes prioritization of countermeasures at high-risk crossings by reviewing the causes of accidents and available control measures at these locations.

Given the increasing number of rail infrastructures and resulting railway grade crossings across the globe, accidents at railway-highway grade crossings are considered to be a critical rail safety issue associated with the rail safety management area. Although these accidents generally arise from several factors that are largely outside of railroad control, the rail industry is committed to making enormous efforts aimed at sharply reducing the frequency and consequences of grade crossing accidents.

The research also contains the results of risk assessment model development based on railway accidents scenarios as a common approach for hazard analysis and risk assessment in railway sector. It is a start point of railway system safety management and represents a quantitative risk assessment model which is based on accident scenarios. The developed model will provide a generic model of the safety risk on the DFCCIL railways which will increase the industry’s knowledge of the risk from the operation and maintenance, allow the identification of areas of railway operation that need further risk controls, allow sensitivity analyses to be carried out to determine the risk reduction from the introduction of new control measures and allow cost benefit analysis of proposed changes.

The developed model is being prepared currently and will include:

1) The feasibility and uncertainty test in the results of the developed model,
2) Improved level of human factors modeling and

3) Use of more sophisticated statistical analysis techniques where only limited data is available for some of the required inputs.

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