Resilient Transport Systems and Services: The case of India's Railway System

Arun Saksena[1] and Debabrata Dalal[2]

ABSTRACT

Natural hazards and man-made disasters have an adverse impact on the transport system. Existing vulnerabilities within the transport system exacerbate the impact of such disasters. Infrastructure managers follow a two-step approach. The first step is planning, designing and executing a system that helps to prevent and minimise the impact of disruptions caused by disasters. This includes real-time condition-monitoring systems to prevent the occurrence of disasters wherever possible. The second step involves building a sufficient coping strategy to assist in post-disaster recovery and restoration. Reducing existing vulnerabilities helps to lessen the severity of a disaster's impact on the transport system and facilitates faster recovery. Indian Railway entities bring rail and other experts together to share good practices and issue guidelines on how to optimise cost-effective resilience, prioritise resilience activities, and source funding for investment to build future resilience.

Most rail transport engineering systems are designed with a passive and fixed design capacity. This design often makes their response to disasters unreliable. These transport systems are designed with system redundancies to ensure the required level of availability to operate. However, a high level of system redundancies increases a system's life-cycle cost. A more proactive maintenance approach would help to detect, diagnose, and predict the effects of adverse events. Incorporating these proactive methods at an early design stage has the potential to transform passively reliable (or vulnerable) systems into adaptively reliable (or resilient) systems, all while reducing costs. This paper proposes a resilience-focused system for designing transport systems, with a specific focus on building resilience in the railway network.

Key words: resilience, vulnerability, susceptibility, capacity, reliability, prediction, railway

1. INTRODUCTION

Increasingly extreme natural phenomena and disruptive climate events have been witnessed across many regions of the world. The increasing frequency and extremity of these events have had an adverse impact on the built environment. Transport infrastructure and services are subject to heavy damage caused by floods, land-slides, storms, cyclones, wild-fires and earthquakes. Infrastructure in mountainous terrain, coastal areas and near riverbanks are particularly at risk. Between 1970 and 2018, the average number of people affected annually by natural disasters in Asia and the Pacific was 142 million and the average number of fatalities per year was 42,000 (UNESCAP, 2019). Overall economic losses from the 2004 Indian Ocean earthquake and tsunami disaster are estimated to be around US$ 10 billion, with major damage caused in Indonesia, Thailand, Sri Lanka, and India. These losses include severe damage to infrastructure, including roads and railways, systems for water supply and electric power, as well as schools and hospitals. The Asia-Pacific region suffered damages and losses equating to US$ 266.8 billion out of US$ 366 billion globally in 2011 (NDMA, 2012). In the last decade, the number and severity of disasters, including floods, earthquakes, storms, landslides, have led to the immense loss of life and property, thereby hampering development and disrupting trade. India is more prone to disasters due to geo-climatic conditions and a high degree of socio-economic vulnerability. Between 2001 and 2010, World Bank data revealed losses of US$ 1.2 trillion due to climate change and natural disasters (UIC, nd) (Figure 1). In light of this, the International Union of Railways (UIC) has embarked upon a strategy framework to build long-term resilience in rail transport under the Rail-Adapt

[1] Senior Fellow, Asian Institute of Transport Development, New Delhi
[2] Consultant, RailTel Enterprise Limited, New Delhi.

Initiative. The initiative brings together rail and other experts to share good practices and develop common guidance on how to optimise cost-effective resilience, prioritise resilience activity, source funding for the necessary investment, and forge connections with International Finance Institutions (IFIs) and other development banks.

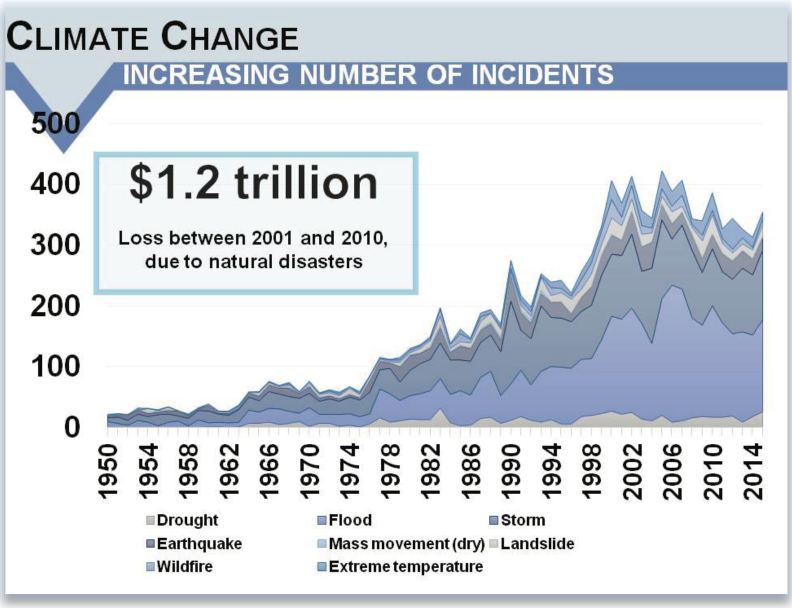

Figure 1: Climate change – increasing number of incidents (source: UIC)

Natural and man-made disasters cause widespread disruption. They lead to the loss of human lives and adversely affect the economy, often exceeding the ability and capacity of a society to cope up with its existing resources. Disasters are classified as either "natural" or "man-made." Disasters which result from human action and/or inaction, including chemical or industrial hazards, environmental pollution, transport crashes and societal unrest, are classified as "man-made" or "man-induced". However, the current social understanding of disasters views this distinction as artificial, as most disasters result from the action or inaction of people and their socio-economic behaviour. Living in a manner that degrades the environment, such as developing and over-populating urban centres, or creating socio-economic systems without attention to ecological balance, can lead to man-made disasters. Communities in areas susceptible to river flooding, earth tremors and nuclear power units are highly vulnerable. Disasters are further compounded by seasonal and sudden fluctuations that can make the timing, frequency and magnitude of their occurrence more difficult to predict. Transport systems and communication services are vital for socio-economic growth and provide a lifeline for many regions to fulfil their development goals. To mitigate the adverse effects of disasters, transport systems must have more resilient operations in place. Building resilience will provide necessary relief on transport services when a disaster does indeed occur, and will allow time for infrastructure assets to be restored.

2. SUSTAINABLE DEVELOPMENT GOALS

The United Nations have outlined 17 Sustainable Development Goals (SDGs) to be achieved by the year 2030 (United Nations, 2015a). SDG-9, related to industry, innovation and infrastructure, is oriented to "build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation" and SDG-11 is focussed towards building sustainable cities and communities - "to make cities and human settlements inclusive, safe, resilient and sustainable." In addition, SDG-11 stipulates the aim of creating safe, affordable, accessible and sustainable transport systems for all. This is to be achieved by improving safety and expanding public transport in order to reduce the number of deaths and the number of people affected, as well as to decrease the economic losses caused by disasters.
Resilient transport infrastructure forms the backbone of a prosperous economy, providing access to markets, jobs and social services. For this reason, SDG-9 calls for increased access to sustainable

transport infrastructure in less developed countries. As per estimates, collectively these less developed countries will need to spend between 1 to 3 percent of Gross Domestic Production (GDP) annually on new transport infrastructure by 2030, with an additional 1 to 2 percent for maintenance (World Bank, 2019). Securing resources for maintenance is crucial to ensure the continued safety and reliability of transport systems, but many countries have struggled to sustain their spending on maintenance.

SDG-13 stipulates countries to strengthen the resilience and adaptive capacity of all public infrastructure. It stresses the urgent need to combat climate change and mitigate its adverse effects, particularly on transport systems. Moreover, the Sendai Framework for Disaster Risk Reduction (United Nations, 2015b) stipulates improved risk management while building and managing infrastructure networks. Proactive policies, directives and regular reviews of infrastructure planning and design standards are particularly important for developing countries. Their investment needs are high, but risk assessments are often scarce and the potential impact of disasters are either underestimated or go undetected.

3. INDIA'S TRANSPORTATION SECTOR

India's transport sector is large and diverse and caters to the needs of more than 1.3 billion people. In 2007, the sector contributed about 5.5 percent to the nation's GDP, with road and rail transportation largely providing physical connectivity to remote urban and rural regions. This paper defines "Resilient Transport Systems and Services" to mean providing transport between any two points, using any mode on demand. Given the current transportation infrastructure in India, it would be unwise to depend on only one mode of transport from a resilience perspective.

The Indian Railway (IR) is one of the largest railways under single management. On a total route network of 67,415 kilometres in March 2019, IR carried more than 23 million passengers and 3.36 million tonnes of freight daily in the financial year 2018-19 (MOR, 2019). Annual passenger traffic stood at 8.4 billion, as compared to 1.3 billion in 1950-51. Around 1.2 billion tonnes of freight were transported, as compared to 73.2 million tonnes in 1950-51. This mainly included bulk commodities such as minerals, ores, steel, fertilizers, petrochemicals and agricultural produce to remote corners of the country.

The IR has undergone significant changes and advancements. These include: the movement of block rakes; the construction of new lines and doubling tracks; the provision of rail flyovers, underpasses, road overbridges and rail bypasses with electrification; the application of decongestion techniques; embedding advanced signalling, train control and automation; the segregation of freight corridors, and the increasing of rail speeds to 130/160 kmph. These strategic changes have been introduced following an evaluation of available technologies in rail transport. They have been incorporated into the IR system based on their affordability and ability to be customised according to local needs. Although the IR system provides an important lifeline to remote areas and creates cross-border linkages, many of the system's major corridors suffer from a capacity constraint and require capacity-building plans. Rail transportation has a number of favourable characteristics when compared against road transport. For example, it is six times more energy-efficient and four times more economical (Kumar, 2019). Rail construction costs are approximately six times lower than road for comparable levels of traffic. It is also the only major transport mode capable of using any form of primary energy.

4. DEFINING RESILIENCE AND THE MODEL FOR ASSESSMENT

This paper defines transport resilience as the ability to avoid and recover from sources of adversity, disturbance, damage or catastrophe that affect system performance (NIAC, 2009). Resilience is also defined by a system's ability to adjust and adapt in the face of disturbances and unpredicted changes (Hollnagel et al., 2006). Resilient systems can sustain the impacts of external and internal disruptions without interruption or change to performance, and are able to recover rapidly and completely in case of disruption (ASME. 2009). In the context of engineering systems, resilience is defined as the sum of the passive survival rate (reliability) and the proactive survival rate (restoration) (Youn et al, 2011). The transport sector and its infrastructure have been recognized as important contributors to the national economies and societies, with some studies carried out on their resilience (Percoco, 2004). Resilience should not be mistaken for stability (Meadow and Earthscan, 2009). Resilient systems can be very unstable. For example, short-term oscillations, periodic outbreaks, long cycles of succession, climax, and the collapse of natural phenomenon may represent a normal unstable condition. Resilient transport systems are those that can respond successfully to such vulnerable situations.

4.1 Resilience in Transport Systems

Recent research on resilience in transport systems has largely focused on climate change and extreme weather. Initial investment in their durability helps to ensure that a transport system requires fewer resources to keep it maintained in the future. A comprehensive asset management program and predictive maintenance strategy also help to improve a system's resilience. Moderate upgrades, enhanced and proactive maintenance and more effective information sharing can reduce lifecycle costs. Investing in resilience strategies ensures transport systems will be safer and more efficient in the future.

One of the most cost-effective means to enhance resilience is information management. Real time data of system components and external interferences can be used to predict the likelihood of disruption, thereby allowing transport management to take immediate preventive steps to avoid a catastrophe, minimize the potential impact and take steps to ensure an alternative outcome Further, once one mode of transportation fails (e.g., train), the information on the nature of the failure, its duration and alternative services available for passengers, can become attributes of resilience. Passenger information has been conventionally associated with service level and comfort, but it can also be utilised in the context of fostering resilience.

Transport systems are comprised of several subsystems. These subsystems are more manageable for infrastructure owners and decision makers because they segment components of resilience and provide scalable indicators of the system's operations. This resilience model can be applied to transport infrastructure and used as a starting point for the initial engineering stage and in the assessment of risks. Designing resilience or appraising the existing reliance of a transport system is a holistic and extensive task. The model proposed in this paper may be regarded as a practical tool. The model is proposed to be applied, developed and operationalised by the Finnish Transport Safety Agency for ensuring safety and reliability aspects of transport system (FTA, 2015).

4.2 Components of Resilience

Resilience is the inverse of vulnerability in a system (Leviäkangas Pekka, 2015). Vulnerability is a function of exposure, susceptibility and coping capacity (Molarius et al, 2014). The Disaster Reduction Terminology in UNISDR Report (United Nations, 2009) highlights the following:

- *Coping capacity: the ability of people, organizations and systems, to use available skills and resources in order to face and manage adverse conditions, emergencies or disasters.*
- *Exposure: people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses.*
- *Vulnerability: the characteristics and circumstances of community, system or asset that make it susceptible to the damaging effects of a hazard.*

Molarius et al. (2014) presented the following conceptual model for vulnerability and resilience:

$$Vulnerability = \frac{Exposure \times Suseptibility}{Coping\ Capacity} = \frac{1}{Resilience}$$

$$Resilience = \frac{Coping\ Capacity}{Exposure \times Suceptibility}$$

Leviäkangas (2015) has also discuss the application of the above resilience model. Resilience indices may be calculated by using statistical data available in publications and applying the model above.

4.3 Subcomponents Description

The components of resilience can be separated into subcomponents and attributes. Levels of exposure can also be separated. Coastal and river railways are more exposed to sea storms and flooding, and networks in mountainous areas to landslides and avalanches. Resilience is the Ratio of the System Strengths and Weaknesses as given below:

$$Resilience = \frac{Resources, Skills, Features_{(Strength)}}{Risk, Sensitivity,\ Features_{(Weakness)})}$$

To explain the potential use of the resilience model, the following attributes in Table 1 can be incorporated as shown in Figure 2.

Table 1: Attributes of resilience

SNo	Attribute	Explanation - Example
1	Risk	Probability of an adverse event – heavy rains, flooding, land slide etc.
2	Feature Weakness	Worn-out components of infrastructure – end of useful life or poor quality leading to higher failure rate.
3	Sensitivity	Components without backup – critical standalone system like Overhead Electrical Equipment (OHE).
4	Co-variance	Dependence on environment, other components/sub-systems – power supply.
5	Resources	Skills, warning systems, availability of quality spares, tools, budget
6	Feature - Strength	Reliable design, engineering and construction practices like factor of safety, redundancy.
7	Hedging	Protective framework, standby systems, insurance.

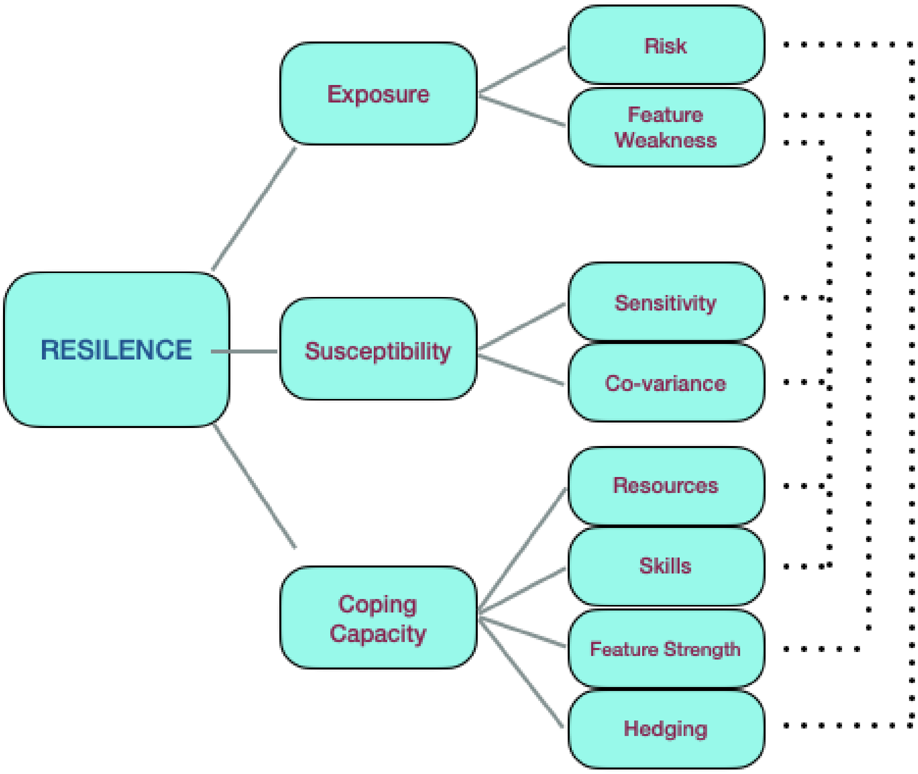

Figure 2: Resilience conceptual hierarchy **(**The dotted lines between attributes represent individual perception of their inter-dependencies)

4.4 Components of Railway Transport System

Applying this concept of resilience to transport infrastructure is demanding for several reasons. Firstly, it comprises several interconnected subsystems, which are inherently complex. Further, the transportation modes (rail, road etc.) differ widely in relation to technology and systems, network capacity, monitoring and governance, customer profile and marketing.

There is no universally accepted definition of what comprises a transport system because the components and subsystems of each mode are different. In the rail network, several specific subsystems like rails, bridges-culverts and their substructures, rolling stock and traction power, electricity, signalling and communications, operations, safety and control mechanisms exist in addition to stations, terminals, shunting yards, depots and workshops. Table 2 shows indicatively some subsystems of the rail transport system.

Table 2 – Components of railway transport system

Transport Mode	Supplementing Structures	Sub Systems	Nodes
Railways	Stations, Rail Tracks, Tunnels, Bridges	Rails, Bridges/Culverts, Track bed, Crossovers, Stock and Switch Rails, Sleepers, Ballast, Tunnels, Over Head Traction Catenary, Interlocking & Blocks, Colour Light Signals, Point Machines, Track Circuits, Digital Axle Counters, Level Crossings, Locomotives and Rolling Stock etc.	Terminals, Stations, Shunting Yards, Connection to other Modes

4.5 **Resilience – Transport System Matrix**

As the attributes and qualities of subsystems vary widely, a uniform approach to the management or enhancement of their resilience must be adopted. In Table 3, the generic resilience component and attribute structure is combined with transport infrastructure system model, where multiple needs can be accommodated within the Resilience Matrix. The matrix can be modified, expanded, simplified and improved as required.

Table 3 - Resilience matrix

Transport Subsystems		Resilience								
		Exposure			Suceptibility		Coping Capacity			
		Risk	Features / w	Sensitivity	Sensitivity	Covariance	Resource	Skills	Features / s	Hedging
Pathways	Roads									
	Rails									
	Waterways									
Nodal Points										
Supplementary Structures										
Supplementing Systems										

The ownership and governance structure for resilience enhancing strategies and associated issues are not clearly laid down. Queries and issues will be raised at the time of investment decision and long-term resource allocation - Who needs resilience? Who will pay for it? Who will bear the recurring costs?

The Finnish Transport Safety Agency intends to use the matrix to capture the potential parameters and to assess each attribute's quantitative valuation to make resilience measurable, manageable and understandable (FTA, 2013). Therefore, the proposed framework enables breaking-up the challenges into subsystems and investigating each resilience component and attribute at a time, instead of trying to solve all challenges together. This approach provides tools to overcome the problem of general views and paves the way for a more detailed, structured analysis. Entities, who are responsible for not only transport systems, but also of other critical infrastructures like water supply, sanitation, energy and electricity, face a more serious challenge to prioritise their efforts and to assess the interdependencies of different infrastructures. Capacity development covers the strengthening of institutions and mechanisms at all stakeholder levels. UNISDR (United Nations, 2009) defines 'Capacity Development' as "*the process by which people, organisations and society systematically stimulate and develop their capability over time to achieve social and economic goals, including through improvement of knowledge, skills, systems, and institutions – within a wider social and cultural enabling environment*."

5. STATUS AND INITIATIVE FOR RESILIENCE ON INDIAN RAILWAY

The above model for resilience evaluation and assessment may be applied on segments of IR. The current status is discussed in the forthcoming chapter.

The planning and development of capacity and connectivity on the IR network is based on inputs received from various stakeholders, state governments, ministries, public representatives, industries and associations. However, a more holistic view of railway infrastructural needs is required in terms of standards, technologies and network design to ensure minimal disruption. Table 4 below highlights the outcomes due to consistent development efforts of IR and resilience attributes of important components and sub-systems of fixed infrastructure of railway are explained.

Table 4: Growth of Indian Railways

Indices of Growth of Traffic Output and Inputs (1950-51=100) *****Revised							
Financial Year	**Traffic Output Indices**		**Investment Input Indices**				
	Freight Traffic (Net Tonne Kms) (Revenue+ Non-Revenue)	**Passenger Traffic (Non-suburban Passenger Kms)**	**Wagon capacity**	**Passenger coaches**	**Route Kms.**	**Running track Kms**	**Tractive effort of locos**
1950-51	100	100	100	100	100	100	100
1960-61	199	110	152	154	105	107	144
1970-71	289	159	226	188	112	121	178
1980-81	359	279	269	210	114	128	201
1990-91	550	394	278	219	116	133	192
2000-01	715	614	246	254	118	138	233
2012-13	1,475	1,512	325	367	122	150	390
2016-17	1,407	1,675	385	409	125	155	475
2017-18	1,571	1,715	393	413	125*	159*	494
2018-19	**1,675**	**1,685**	**409**	**422**	**126**	**162**	**528**

The Railway Track is the main component of the rail transport system. The safe running of trains at maximum permissible speed depends on the availability of a stable track maintained within safe parameters. Rails are sensitive to climatic variations. This thermal stress leads to corrosion, buckling or fractures. The risk of damage by natural hazards is currently mitigated by intensive activities with multiple layers of patrolling, maintenance, inspection and repairs through manual and mechanized means, which are systematically monitored. Track geometry is observed in periodical runs of Track Recording Cars (TRC) and vulnerable spots are advised for correction. Real time monitoring of rails is increasingly required to detect adverse conditions due to low winter temperatures, when cracks lead to broken rails and minimize risk. Track Circuits using both the rails, Ultrasonic Detectors and Optical Fibre Cables (OFC), have been tried on a small scale for detecting rail cracks early. Wheel flats and rail fractures can be detected by optical reflectometers connected to OFC laid parallel to the track by sensing of track vibrations leading to back-scatter of light. Land slide detection systems have been used by one of the Railways. IR has been working to reduce these weaknesses within the components to improve coping capacity and overall resilience.

The design layout of the tracks, along with corresponding signalling and overhead electrical equipment (OHE), is built to be flexible and reliable. Resilience has been improved by the provision of alternative signalled routes for yard layouts, isolation with simultaneous reception and dispatch facility, twin single line working, subsidiary backup signals (Calling On, Shunt), redundancy in train detection, higher factor of safety in power supply design and centralized hot standby interlocking and remote control. Fall back manual train operation procedures and temporary working orders are part of Standard Operating Procedures (SOPs). All these measures have contributed significantly to reduce system failures.

The Track Circuit gets short circuited by the presence of train axles and provides a means for detection of a train vehicle. It is the most basic device for reliable train detection but is susceptible to failure when the track gets wet or water logged. IR has made considerable strides to implement track circuiting for safe train detection at stations and 96.6% of all BG station have been covered. This has also provided partial rail breakage detection in order to strengthen the safety of the system.

Signals: Interlocking and Block signalling are vital for safe and efficient operations in yards and pushing them at close headway in the section. Route Relay/Panel/Electronic Interlocking (RRI/PI/EI) along with

Multiple Aspect Colour Light Signals (MACLS) have been provided at about 5886 stations (94% stations March 2019). These systems have the capacity to recover quickly. The replacement of old outdated, multi-cabin mechanical signalling equipment by electronic interlocking with hot standby has reduced system weaknesses. The provision of MACLS fed through underground cables has made the system more robust and less susceptible to interference and adverse weather conditions. Shifting block equipment from disturbance prone overhead lines to underground cables, provision of electronic non-cooperative blocks, Block Proving by Axle Counters (BPAC) and Intermediate Block (IBS) and Automatic Block Signalling (ABS) has improved safety and reliability.

Operations Control Centre (OCC): The management of train movements is largely performed manually. A centrally located train controller is typically responsible for a specific sector or station. Trains are signalled by the station master posted at each station, who records details based on feedback received by telephone. The main weaknesses in manual control centres are inefficient utilisation of the track, sluggish control of movements, errors in operations and reporting, congestion, inadequate maintenance time and absence of real time planning. IR attempted to strengthen the system by automating the information needs of the controller and customer via a video display of the entire rail network in the form of the Train Management System (TMS). TMS was installed on congested sections of Central, Eastern and Western Railways. Maintenance and operations were improved, providing real time train charts and real time accurate information to customers. OCC was provided at Tundla (Figure 3) on Prayagraj division of North Central Railway (NCR) for remote operations and control of trains on a section of about 440 kms having 40 stations. All relevant information relating to signals, track occupancy, point/switch status, route setting, level crossing gate status, train number and attributes of crew and rolling stock, local control panel status, parameters of functions and their status is aggregated and displayed on a video wall in the OCC on a real time basis. Train operations have also been improved by making use of stored/long route settings, automated control charts, train conflict resolution, maintenance planning, punctuality control and accurate passenger information forecast.

Figure 3: Operations control centre Tundla, North Central Railway

25 kV Electrification: 25 kV Electrical Traction Power network supplies power for electrical locomotives. 51% of the routes on IR spread across 34319 kms are electrified as of March 2019 (MOR, 2019). Electric traction consumes substantial energy, which is increasing steadily, and requires real-time monitoring of sub-systems for optimum usage, power factor control and functioning. Resilience has been improved by the Realtime monitoring of transformers, circuit breakers, lightning arrestors, and interrupters, using a Supervisory Control and Data Acquisition (SCADA) System and Remote Control (RC). SCADA systems monitor, store and analyse various parameters including catenary current, voltages, power factor, indications and device status using telemetry from switching and sub-stations, which help to identify faults and facilitate rapid recovery. Remote Controls operate without the need for human intervention, which enables faster restoration and recovery after a disruption. The engineering data in combination with AI to identify patterns of failure and highlight weaknesses.

Mobile Train Radio Communication (MTRC): The communication of information is key to an efficient, safe and resilient transport system. The Global System for Mobile Railways (GSM-R) has an emergency built-in communication feature. This has been rolled out on some sections of IR using fibre-optic cables. GSM-R exists on the more vulnerable rail network between New Delhi and Guwahati on the eastern route and New Delhi and Jhansi towards the south. An save our soul (SoS) button on the user terminal can be used for emergency situations like heavy rains, fog, flooding, storms or accidents on the rail route. Communication between train crew and station staff is vital for preventing holdups, resolving conflicts and avoiding accidents.

IR has also implemented predictive maintenance measures to integrate rolling stock parameters such as wheel impact load detection (WILD) (Figure 4). This will help to check for developing defects automatically, thereby reducing risk of disruption.

Figure 4: Integrated rolling stock parameters detection systems on IR.

Rolling Stock Initiatives: Passenger coaches on IR are provided with a crash buffer and anti-climbing mechanism. These absorb excess collision energy and reduce the risk of injury and loss of life. To make the rail coaches fire resistant, fire detection and alarm systems have been provided.

IR Rail Network Initiative: To ensure a more resilient rail network on the congested eastern and western routes of IR, a separate rail corridor dedicated for freight traffic is under implementation (Figure 5). From a co-variance point of view, it may be assumed that the two sets of networks are independent from each other. Disruption in one may not impact the other. The freight trains would be separate from the passenger trains to reduce over-burdening one of the systems. In the event that one system is disrupted, rapid restoration and recovery can be done by a switch over to the other network.

Figure 5: Dedicated freight corridors – East and West

6. INITIATIVES ON IR FOR DISASTER RECOVERY

Disaster Risk Management: IR has an organized system of relief, rescue, restoration and rehabilitation operations for managing train disasters and natural calamities. Accident Relief Medical vans (ARMVs) and Accident Relief Trains (Figure 6 - ARTs) are on hand to provide medical assistance. Communication facilities are made available to passengers and railway officials to empower them to take decisive action to mitigate the effects of a disaster. Steps are taken to provide prompt and effective relief to the affected passengers in the event of any train accident. The senior-most officer at each site takes full responsibility for the situation, and supervises the overall relief operations. Special inquiry booths are opened at originating, terminating and important stations enroute.

Figure 6: Accident relief train

Disaster preparedness: The National Disaster Management Plan promulgation of the Disaster Management (DM) Act in 2005 showed a commitment to adopt a more collaborative strategy to disaster preparedness. Based on recommendations made in the Railways Disaster Management Plan (Indian Railways, 2019), the plan broadened its scope to include a wide range of incidents, including terrorism related activity and natural calamities. The aim is to share resources with other governmental departments to make the IR system more resilient.

7. CONCLUSIONS AND RECOMMENDATIONS

This paper introduces a framework that can be used to assess a rail network's resilience and ability to recover from disaster. Natural hazards and man-made disasters have an adverse impact on the transport system. Existing vulnerabilities within the transport system exacerbate the impact of such disasters. Reducing existing vulnerabilities helps to lessen the severity of a disaster's impact on the transport system and facilitates faster recovery. In putting forward the recommendations the paper hopes to stimulate discussion and bring railway operators and other experts together to share good practices and consider approaches and guidelines on how to optimise cost-effective resilience, prioritise resilience activities, and source funding for investment to build future resilience.

When the global pandemic struck, there was total disruption of normal operations of all modes of transportation due to restrictions imposed to stop the spread of COVID-19. IR provided assistance by transporting essential goods across the nation during the continued lockdown ensuring that there was no shortage of essential goods. Trains hauled a number of truckloads of freight containers (Figure 7) to reduce congestion on roads and the susceptibility of the truck drivers to the impacts of COVID-19 pandemic.

Figure 7: Long container wagons freight train

Based on the ideas explored in this paper, the following recommendations may be considered for adoption:

- Coordination across all stakeholders should be strengthened and the focus should be on building transport capacity and resilience at local, national and international levels, integrating transport in programs and activities through coherence between sectors/entities.
- Risk and vulnerability assessments of existing transport systems, as well as new project proposals, should focus on building resilience. The Framework model suggested in this paper may be used.
- Transport infrastructures should upgrade and adopt technical standards that are climate resilient. They should have the appropriate capacities to integrate a new system design and means of operation. This includes emergency preparedness and regular maintenance.
- Emphasis should be placed on telemetry, monitoring, evaluating and reporting passenger user data to improve predictions and prevent future disruptions.

REFERENCES

American Society of Mechanical Engineers (ASME) Innovative Technological Institute (ITI), Washington, (2009) All Hazards Risks and Resilience. https://files.asme.org/ASMEITI/RAMCAP/17978.pdf

Finnish Transport Agency (FTA)'s Operating and Economic Plan 2015 - 2018 to the Ministry of Transport and Communications, (2013)

Hollnagel, E., Woods, D.D., Leveson, N. (2006) Resilience engineering: concepts and precepts. Quality & Safety in Health Care Journal, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2464899/

Indian Railways - Accident Manual of North-Central Railway, (2012) https://ncr.indianrailways.gov.in/cris//uploads/files/1574851430079-Accident%20Manual%2027.11.2019.pdf

Indian Railways - Disaster Management Plan, (2018), https://indianrailways.gov.in/railwayboard/uploads/directorate/safety/pdf/2018/DM_Plan_2018.pdf

Indian Railways – National Rail Plan 2030, (2016) http://www.indianrailways.gov.in/railwayboard/uploads/directorate/prd/PR/MR_Inaug_Website_08122016.pdf

Indian Railways – Vision 2022 Plan, (2017), https://indianrailways.gov.in/Reform-Perform-Transform%202022_v10%20(2).pdf

International Union of Railways (UIC), Building a Resilient Railway – UIC Rail Adapt Project https://uic.org/IMG/pdf/railadapt.pdf

Kumar, B., (2019), Freight Transport in Indian and Dedicated Freight Corridors, Journal of Dedicated Freight Corridor Corporation of India Limited, Issue III, pp 30.

Leviäkangas Pekka, Aki - Resilience of Transport Infrastructure, (2015), Department Transport, VTT Technical Research Centre of Finland Ltd., Oulu, Finland, CSID Journal of Sustainable Infrastructure Development 1:80-90pp 83

Meadow, D.H., Earthscan, London, (2009), Thinking in Systems, pp77. https://wtf.tw/ref/meadows.pdf

Ministry of Railways (MoR), (2018), India - Indian Railway Year-Book http://www.indianrailways.gov.in/railwayboard/uploads/directorate/stat_econ/Year_Book/Year%20Book%202018-19-English.pdf

Ministry of Road Transport and Highways (MoRTH), Basic Road statistics of India, (2019) – pp23-26 https://morth.nic.in/sites/default/files/Basic%20_Road_Statics_of_India.pdf

Molarius et al (2014). Resilience of Transport Infrastructure pp https://www.researchgate.net/publication/283072091_Resilience_of_Transport_Infrastructure_Systems

National Disaster Management Authority (NDMA), India, (2012), Guidelines – Management of Tsunami – Chapter 4.7 Financial Impacts of Disasters-Global Scenario pp 21. (https://shodhganga.inflibnet.ac.in/bitstream/10603/8619/2/11%20chapter%204.pdf)

National Infrastructure Advisory Council (NIAC) Washington, Critical Infrastructure Resilience, Final Report and Recommendations, (2009), pp8.

https://www.cisa.gov/sites/default/files/publications/niac-critical-infrastructure-resilience-final-report-09-08-09-508.pdf

Percoco, M. (2004), Network and Spatial Economics Infrastructure and economic efficiency in Italian regions 4, 361–378, https://www.academia.edu/10295357/Infrastructure_and_Economic_Efficiency_in_Italian_Regions

Technology Information Forecasting and Assessment Council (TIFAC), Department of Science and Technology (DST), India. (2016), The Technology Vision 2035 – Technology Road Map Transportation, Executive Summary pp xvii and Introduction, pp 29http://tifac.org.in/images/tifac_images/2035/tv2035/trans_roadmap.pdf

United Nations - Strategy for Disaster Reduction (UNISDR), (2009) https://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf

United Nations (2015a) Transforming Our World – Agenda for Sustainable Development pp14-16 https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

United Nations (2015b) – Sendai Framework for Disaster Risk Reduction - Guiding Principles pp13 https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf

United Nations Economic and Social Commission of the Asia Pacific (UNESCAP), (2019). Asia-Pacific Disaster Report 2019, Chapter I – The Asia-Pacific Disaster Riskspace, pp 7.

World Bank Group – From a Rocky Road to Smooth Sailing – Building Transport Resilience to Natural Disasters, (2019) pp 2. https://pdfs.semanticscholar.org/2d2d/c268054aba1f54a8493cda0540f764625ac2.pdf?_ga=2.104527938.353183014.1603042852-2080347380.1603042852

Youn, B.D., Hu, C., Wang, P, (2011), Resilience-driven system design of complex systems. Journal of Mechanical Design, Vol 133