CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Indian Railways (IR) is one of the largest transport and logistics network of the world with more than 65400 route km (115833 track km), 7172 stations, 136286 bridges, 9913 locomotives, 63870 coaches and 244731 wagons. IR operates about 20000 trains each day comprising 12600 passenger trains and 7400 goods trains. It transports 2.76 million tonnes of freight traffic and 23 million passengers every day (Govt. of India, 2014a). IR has 1.3 million employees and an annual revenue base of Rs.159248 Crore, as on March 31, 2015 (*Govt. of India, 2015b*).

Passenger traffic on IR is broadly classified into two groups, sub-urban and non-suburban. Sub-urban trains are mainly local train services provided by EMU (Electric Multiple Unit) train sets in large metropolitan cities like Mumbai, Delhi, Chennai and Kolkata etc. Sub-urban trains carry about 53 % of the total passengers (Govt. of India, 2014a). Non-suburban passengers trains are mainly of three types viz. ordinary passenger trains, mail express trains, Rajdhani/Shatabdi and similar trains.

High speed trains are those trains which run at a speed of 200 kmph and above on the existing upgraded tracks or at a speed of more than 250 kmph on the new dedicated high speed corridors; specially built for such trains. Trains running at 160-200 kmph on the existing upgraded tracks are semi-high speed trains.

Mail Express and Rajdhani/Shatabdi trains cater to medium and long distance travel needs. Hence, speed of passenger trains is important to the passengers travelling by these trains. Presently, maximum permissible speed of Mail Express and Rajdhani/Shatabdi trains on IR's broad gauge network is 110 kmph and 150 kmph respectively. Average speed of Mail Express trains on broad gauge tracks is 50.4 kmph (*Govt. of India, 2014a*). Average speed of Rajdhani/Shatabdi and similar trains varies from 59.1 kmph (Dibrugarh Rajdhani) to 93.1 kmph (Bhopal Shatabdi). Among Rajdhani trains, Mumbai Rajdhani is the fastest at 90.5 kmph average speed. Sealdah Duranto, at average speed of 89 kmph, is the fastest among all Duranto trains.

2.1 Early Strategies to Raise Speed

IR made attempts to increase speed of passenger trains long back in the year 1987 when a feasibility study was conducted with the help of Japan International Co-operation Agency (JICA) for Delhi-Kanpur section via Agra (448 km) to run passenger trains at 250 kmph. JICA recommended setting up a new corridor with terminal stations at Delhi, Agra and Kanpur with an anticipated cost of Rs.2200 Crore with following two types of services; (i) super express train at maximum speed to 250 kmph on new corridor of Delhi-Agra-Kanpur, and (ii) long distances express trains at 160 kmph to utilize dedicated track with facility of getting in and out of new corridor at Agra and Kanpur.

In the First Governing Council Meeting (GCM) of Research Design and Standards Organisation (RDSO) in 1988, it was decided to improve passenger train speeds, reduce travel time and increase transport facility. Subsequently, a task force was set up to develop technology for operation of passenger services at 160 kmph on specified mixed routes and at 200 kmph on dedicated routes. As a part of the strategy for railway technology development, a mission termed as Mission-II was assigned with an aim to develop technology for operation of passenger services upto 160 kmph on mixed traffic routes and 200 kmph on dedicated routes. The Mission envisaged import of the rolling stock and locomotives. However, cost being very high (Rs.4.9 Crore per km in 1987); Ministry of Railways closed this Mission in March 2001 (Govt. of India, 2008).

Report of the working group on railway programmes in XI Five Year Plan (2007-12) stated consolidation of the rail share in passenger business, particularly, in long distance and medium distance segment by increasing the commercial speed of passenger trains. It also recommended the introduction of fast services between metropolitan cities with a maximum speed of 150 kmph, with development of high speed corridors on select routes as one of its key strategies for the passenger business. The report proposed to upgrade passenger train speeds to 150/160 kmph in order to improve speeds and capacity on the main trunk routes. It further states that Delhi-Agra-Bhopal-Nagpur-Chennai, Delhi- Kanpur-Lucknow and Delhi-Kanpur-Howrah have already been identified for running of 150 kmph trains and gradually other trunk routes on the Golden Quadrilateral and diagonals would be made fit for running 150 kmph trains.

2.2 Benefits of High Speed Rail

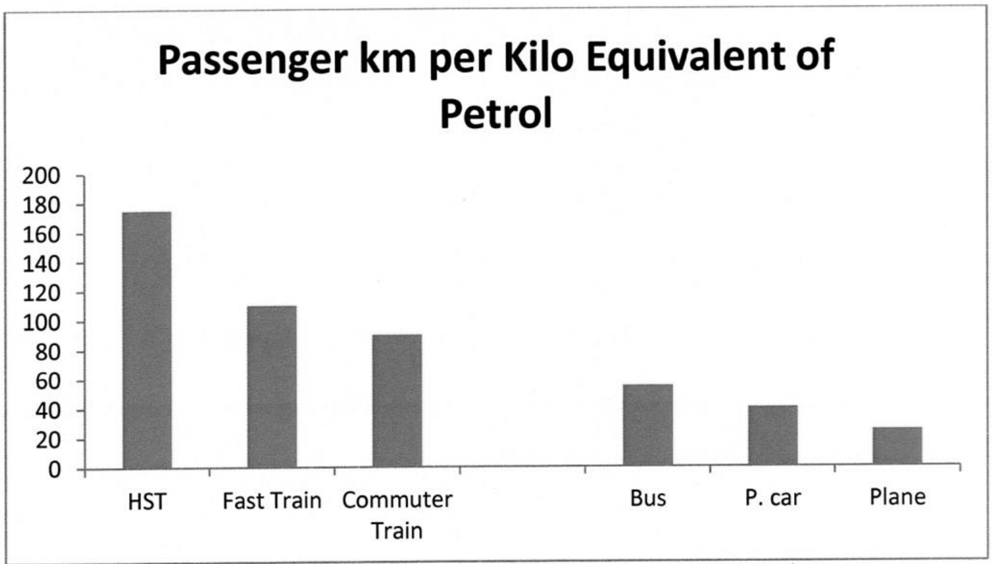
As per Indian Railways Institute of Civil Engineering (IRICEN), High Speed Rail (HSR) imparts following benefits to society (*Govt. of India, 2008*).

(i) Huge Capacity - HSR provides highest capacity in terms of passenger carried per hour per unit use of land. On a double track railway system, 8 trains can run per hour each way, with standard carrying capacity of 800 passengers per train, carrying 12800 passengers per hour and 3 lakh passengers per day. No motorway can provide this kind of capacity that becomes necessary during peak hours. High capacity also helps to reduce traffic congestion and pollution.

(ii) Environment Friendly - Provided HSR services are well priced, very few people like to travel by car. Railroads use only about one third of the land used by a motor way. A standard twin track HSR requires a corridor of 25m width to carry same number of passengers for which a 75 m wide, six lane (2X3) highway is required.

(iii) Energy Efficient – In general, HSR based rail transport systems are about 9 times more energy efficient as compared to airlines and 4 times more than the road transport. A comparison of energy efficiency of High Speed

Train (HST) with other modes of transport has been presented in Figure 2.1. HST imparts about 170 passenger km per kilo equivalent of petrol as compared to 60 for the bus transport, depicting higher efficiency of HSTs.



(Source: UIC Passengers and High Speed Workshop, Rame-Tehran, 30th August 2014)

Figure 2.1 Energy Efficiency Comparison of HST with Other Modes of Transport

(iv) Economic Development – HSR helps in economic development by giving boost to economic activities at the time of construction as well as on completion by facilitating faster movement of human resources at low cost between major cities.

(v) Safest – HSTs are the safest form of transport. These are even safer than normal trains due to use of advanced computer signalling systems, which have a comparatively lower risk of collision.

Semi-high speed rail systems provide all above benefits as HSRs with added advantage that semi-high speed system are cheaper. Another benefit of semi-high speed trains is faster implementation of project as it is achieved by upgradation of existing lines and does not require fresh land acquisition which is a costly and time consuming affair (*Govt. of India, 2015b*).

2.3 Issues in Raising Speed to 160-200 kmph

IR is facing several issues and challenges in achieving its objectives for growth and development of its freight and passenger businesses. The issues pertaining to achievement of IR's vision in general and raising speed of passenger trains to 160-200 kmph (semi-high speed) in particular have been summarised in the following section.

2.3.1 Segregation of Passenger and Freight Traffic

IR aims to raise speed of passenger trains to 160-200 kmph on segregated routes i.e. separate lines for passenger and freight services. For segregation of freight services, IR has already commenced the construction of two Dedicated Freight Corridors (DFCs); one in the western part of the India between Jawahar Lal Nehru Port in Mumbai and Rewari/Dadri in Delhi and the other in the Eastern part of India between Ludhiana in Punjab and Dankuni near Kolkata. Feasibility studies for the other DFCs i.e. North-South Corridor (Delhi to Chennai), East-West Corridor (Howrah to Mumbai), Southern Corridor (Chennai to Goa) and East-Coast Corridor (Kharagpur to Vijaywada) have also been undertaken (*Business Line, 2013*). These corridors, when completed, shall help in achieving substantial segregation of freight and passenger traffic on the trunk routes and improve the speed and reliability of freight as well as passenger services. However, the origin and destinations of traffic do not necessarily fall on the DFCs, hence a number of junction arrangements have been planned to transfer traffic from the existing IR lines to the DFC and vice versa. For example, Eastern corridor will have junctions with the existing track between Ludhiana and Howrah at Dankuni, Andal, Gomoh, Sonnagar, Ganjkhwaja, Mughalsarai, Jeonathpur, Naini/Cheoki, Prempur, Bhaupur, Tundla, Daudkhan, Khurja, Kalanaur, Rajpura, Sirhind and Dhandarikalan. Similar arrangements for interchange of freight traffic shall have to be provided on other DFCs (*Govt. of India, 2009b*).

Segregation of passenger and freight traffic on existing trunk routes depends heavily on completion of DFC projects. Ministry of Economy, Trade and Industry, Japan (METI), in its feasibility study report on upgradation of passenger train speed to 160-200 kmph on existing Delhi-Mumbai routes has presumed that some of the freight traffic on the existing line will be transferred to the planned DFC between Delhi and Mumbai making sufficient room available for passenger trains on the existing line (*METI, 2013*).

2.3.2 Lack of Financial Resources

Sourcing of financial and human resources to execute Railway projects in time is other key challenge that IR is facing. Railway projects suffer from chronic shortage of funds. Available funds are thinly spread over a large shelf of projects. Time and cost-over runs adversely affect the viability of projects (*Govt. of India, 2009b*).

Expenditure in Railways as a percentage of total transport sector expenditure has declined from 56 % in the 7th Plan (1985 - 1990) to 30% in the 11th Plan (2007- 2012). In the last two decades IR has remained under invested (Govt. of India, *2015a*).

IR tentatively needs Rs 1400000 Crore (including Rs 25000 Crore for projects related to raising of speed and another Rs 200000 Crore for construction of 2000 km long high speed lines) for undertaking capacity creation, network expansion and upgradation works over ten year period from 2010-11 to 2019-20. As per Vision 2020 document, 64% of these resources could have been managed through internal generation and extra budgetary resources and for the balance 36% i.e. about Rs. 500000 Crore at the rate of Rs. 50000 Crore per year, IR needed Gross Budgetary Support (GBS) from the Central Government (*Govt. of India, 2009b*). However, as would be seen from the position given in Table 2.1 of capital infusion in IR during six year period from 2009-10 to 2014-15 has been of the order of Rs. 49248 Crore per year which is far below the projected need of Rs. 140000 Crore per year GBS from the Government has been less than the projected requirement of Rs 50000 Crore per year as mentioned in the Vision 2020 document. IR also could not generate financial resources from internal and extra budgetary channels as per target of about Rs. 90000 Crore per year.

Table 2.1: Financing of Indian Railways Annual Plans

(Rs. in Crores)

	Year						
	09-10	10-11	11-12	12-13	13-14	14-15	Average/ Year
Gross Budgetary Support	16911	18385	20013	24132	27033	30100	22762
Railway Safety Fund	805	1100	1323	1578	1983	2200	1498
Internal Resources (DRF+DF+CF)*	12196	11528	8935	9531	9681	15730	11267
Extra Budgetary Resources	9760	9780	14790	15142	15085	17767	13721
Total	39672	40793	45061	50383	53782	65797	49248

. *(Source: Indian Railways White Paper, Feb 2015)*

* DRF – Depreciation Reserve Fund; DF – Development Fund; CF – Capital Fund

As per White Paper presented in the parliament in February 2015, IR bear social service obligation of around Rs. 25000 Crore per year by carrying passenger and freight services below its cost e.g. (i) essential commodities of mass consumption; fruits, vegetables, organic manure, paper, bamboos etc., (ii) concessional passes for sub-urban and 2nd class passengers, (iii) uneconomical branch lines and (iv) new lines opened for traffic in the last 15 years. Reimbursement of this cost to IR has been considered by Government and a Committee of Secretaries had recommended that these be reimbursed to the IR, however the issue remains unresolved till date. Due to under investment in IR, there has been severe congestion on the network resulting in inability of the system to accommodate more trains and increase speed of trains (*Govt. of India. 2015a*). Hence, achievement of all goals as envisioned by IR for year 2020, including semi-high speed on all major trunk routes, is suffering on account of non-availability of adequate financial resources.

2.3.3 Over Saturated Trunk Routes

Lack of physical capacity over IR due to severe congestion on key routes is another issue that is affecting speed of trains. 492 out of total 1219 sections are running at 100% or above line capacity. Situation is further worsened on High Density Network (HDN), comprising major trunk routes lying on golden quadrilateral. Out of total 247 sections on these HDN routes, as many as 161 (65%) are running at 100% and above line capacity (*Govt. of India, 2015a*). These line capacity utilisations are much above the optimal limit of 80 % capacity utilisation for reliable operation (*Govt. of India, 2009b*).

In order to overcome this constraint, IR's Vision 2020 document envisaged augmentation of line capacity on congested routes through doubling/quadrupling of additional 12000 km of lines, increasing total length of such lines to 30000 km by the year 2020 from 18000 km in 2009-10), complete segregation of passenger and freight lines on HDN routes, substantial segregation on other routes, and electrification on busy trunk routes, so that passenger and freight services can have separate double line corridors.

IR classifies all projects related to new lines, gauge conversion, doubling and railway electrification as priority works being related to capacity augmentation (*Govt. of India, 2015a*). A comparative position of target fixed by IR for achievement in these priority areas by the year 2020 and actual achieved by 31st March 2014 has been shown in the Table 2.2.

Table 2.2: Progress of Priority Works for Line Capacity Augmentation

(in Km)	Target 10-20	Year					Average/Year	
		10-11	11-12	12-13	13-14	Total	Target	Actual
New Lines	25000	709	725	501	450	2385	2500	596
Gauge Conversion	12000	837	855	605	404	2701	1200	675
Doubling	12000	769	750	705	708	2932	1200	508
Railway Electrification	14000	975	1165	1317	1350	4807	1400	1202

(Source: IR's Vision 2020, Feb 2009; IR White Paper, Feb 2015)

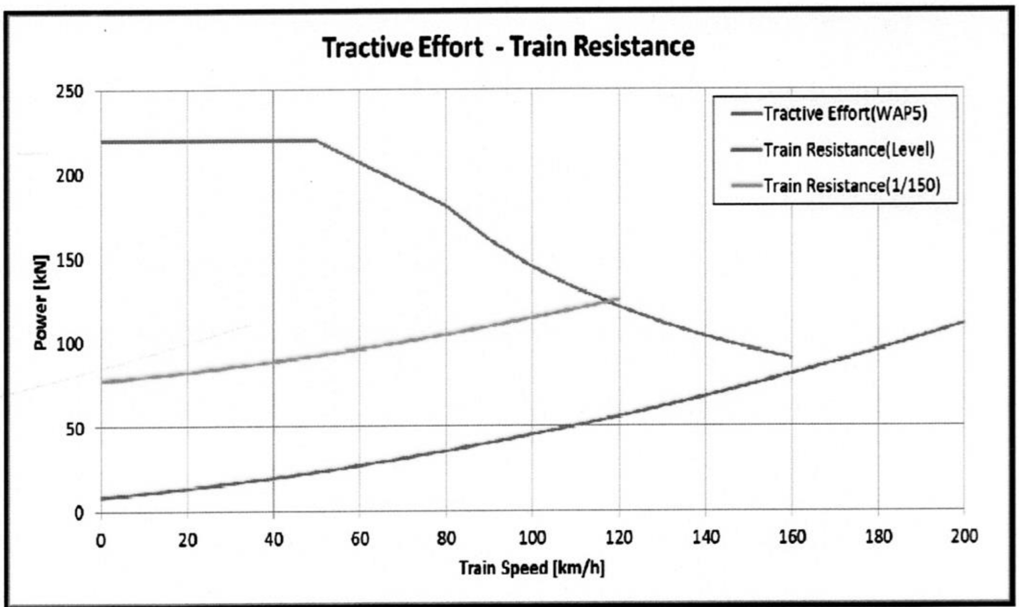
During ten year period of Vision 2020, IR's target was to construct 25000 km of new lines. Against this, 709 km, 725 km, 501 km and 450 km of new lines were constructed in the year 2010-11, 11-12, 12-13 and 13-14 respectively. Thus in four year, total 2385 km of new lines were actually constructed at average rate of 596 km per year against required 2500 km per year. Hence, progress of key works related to line capacity expansion, in the first four year of Vision 2020's total ten year period, has been far below the target.

2.3.4 Rolling Stock for Semi-High Speed

High-horse power locomotives, with Horse Power (HP) ranging from 9000 to 12000 vis-a-vis 5000 at present, are needed to improve speeds and punctuality of passenger train services as well as throughput of goods trains. Train sets need to be introduced for intercity express train services to achieve high speeds and minimize terminal detention (*Govt. of India, 2009b*). Although five out of ten year period of the Vision 2020 has elapsed, High horse power diesel and electric locomotives and train sets are yet to be inducted in the system.

WAP5 (5000 HP Broad Gauge Electric Passenger Locomotive) and WDP4 (4000 HP Broad Gauge Diesel Passenger Locomotive) are the fastest available electric and diesel-electric locomotives respectively with IR. These locomotives are being used for hauling of Rajdhani and Shatabdi Expresses trains and designed for maximum speed of 160 kmph. Similarly, fastest coaching stock, currently available on IR, are Linke Hofmann Busch (LHB) coaches which have maximum permissible speed potential of 160 kmph. IR needs to upgrade and invest in locomotive and coach technologies for formation of passenger trains which are not only safe for operation at semi-high speed of 160 to 200 kmph but also have higher acceleration to achieve maximum speed in 7-8 minutes as per norm (*Govt. of India, 2005*).

New rolling stock for semi-high speed operation is needed due to increased tractive effort requirement of existing trains at higher speeds of 160-200 kmph. Figure 2.2 depicts the tractive effort and train resistance that will be encountered with use of existing Rajdhani trains with WAP5 locomotive and LHB coaches at higher speeds.



(Source: METI's Report on Semi-High Speed Up-gradation of Delhi-Mumbai Route)

Figure 2.2 Tractive Effort Vs Train Resistance at Semi-High Speed

The red and green lines in the Figure 2.2 indicate train resistance at level and 1in 150 gradients respectively. Blue line indicates the tractive effort of the WAP5 locomotives. As is evident from Figure 2.2, present trains can barely run up to 160 kmph speed in a level section and can't go beyond 120km/h speed in 1/150 gradient section (*METI, 2013*).

Train resistance is composed of resistance due to friction, resistance due to adhesion and aerodynamics. Train resistance due to friction and adhesion increases as train weight increases. Thus, reduction of train weight is effective in reducing train resistance. At higher speeds, resistance due to aerodynamics also increases in proportion to the square of the velocity. Therefore, resistance due to aerodynamics is also an important factor for semi-high speed trains and very important especially for bullet train.

Thus, IR needs new rolling stock, suitably designed (to reduce weight) and also shaped (to reduce aerodynamic drag) for high speed running at 160 to 200 kmph.

These requirement may not be met by conventional Rajdhani/Shatabdi trains hauled by locomotives and IR need to go for modern Electric Multiple Unit (EMU) stock capable of quick acceleration/deceleration with superior train resistance performance due to use of shape based on high speed railway technology (*METI, 2013*).

Hence, induction of high horse power locomotives, light weight high speed coaches and train sets are needed for achieving higher speeds of passenger trains between 160 to 200 kmph on existing tracks of IR.

2.3.5 Organisational Restructuring

Efficient execution of projects within time and budget is vital for any organisation to achieve targeted growth and vision. IR has managerial and organizational issues that need to be addressed to fast-track project execution and meet the challenges of massive capacity creation within a short period of 10 years. As per Vision 2020 document, the number of ongoing projects on IR was very large and required resources of the order of more than Rs. 143000 Crore to merely complete such projects. IR planned to achieve high growth by judicious reorganisation of railway activities into distinct business lines and profit centres (*Govt. of India, 2009b*).

Ministry of Railways constituted an Expert Group on modernisation of Indian Railways which submitted its report in Feb 2012. As per their report, organizational reforms are essential in IR to enable to achieve the goals set out for modernization. The structure of the IR has remained largely unchanged for decades. IR continues to be a functionally oriented institution, organized around its cadres instead of businesses or customers. Group recommended re-organization of Railway Board along business discipline e.g. Safety, Business development/ Commercial, Technology/ ICT and Signalling, Freight, Passenger Services, Infrastructure, Finance, HR and PPP. It also recommended organisational changes to empower officials, speed up the decision making process and introduce professional project management systems in IR (*Govt. of India, 2012*).

As per IR's Vision 2020 document, for successful implementation of mission, the organisation has to maintain a balance between the forces of differentiation and integration. IR is organized on departmental lines in terms of functions such as Civil Engineering, Mechanical Engineering, Electrical Engineering, Signal and Telecom, Stores, Security, Traffic, Accounts and Personnel etc. with administrative overlays at Divisional, Zonal and Railway Board level. This structure has been able to deliver so far as competitive landscape had fewer challenges and the task to be performed could be broken down to the simplest elements for specialization by various departments. However, to address increased competition from road and aviation sectors and rising expectations of customers, IR's departmental culture would prove increasingly rigid and incapable of analyzing and responding to the challenges (*Govt. of India, 2009b*).

Rigid organisational structure of IR needs to be reviewed and made more flexible and business oriented for empowerment of officials at field level, speeding up of decision making and efficient execution of mega projects like raising of the speed of trains on existing lines, high speed lines etc.

2.3.6 Under-Recovery of Cost in Passenger Business

IR does not recover full cost of its passenger services, taking all classes of travel together, resulting in losses in this segment. These losses are compensated by cross-subsidization from freight services. Passenger services consume nearly 60% of the network capacity but their share in the total earning is only about 33% (*Govt. of India, 2009b*). IR is facing severe competition from low-cost airlines in long distance and luxury buses in short to medium distance segments due to which premium class passenger fares can't be increased beyond a limit. Second- class fares and suburban fares are seldom increased being critical for the underprivileged sections of society. As a result, IR's passenger business has been a losing proposition.

In the year 2012-13, IR incurred an overall loss of Rs. 26831 Crore, including Rs. 3405 Crore sub-urban losses in metro cities of Delhi, Mumbai, Chennai and Kolkata (*Govt. of India, 2014a*).

Most of the passengers, who are likely to make use of trains on semi-high speed networks, shall be travelling long distance in second class. These passengers are price sensitive and are currently enjoying heavily subsidised train services. Investments in upgrading tracks, locomotives and trains for semi-high speed operation shall be substantial amount in coming years. For desired economic viability, efficient operation and maintenance of such projects at operational stage, it is necessary to generate commensurate additional revenue so as to at least recover cost of capital, operational cost and cost of maintenance. However, this seems to be a distant possibility in the present circumstances where all passenger fares on IR trains are decided based on popular agenda rather than economic and commercial.

2.3.7 Inadequately Defined Mission and Objectives

An important issue that emerges from IR's Vision 2020 Document is inadequate detailing of IR's mission and objectives for achieving its Vision 2020. A mission statement describes what the organisation is now and a vision statement describes what the organisation would like to become. A mission statement promotes a sense of shared expectations in employees and communicates a public image to important stakeholder groups in the organisations task environment. These statements tell what the organisation is, what it does and what it would like to become. Objectives state what is to be accomplished, by when and should be quantified (*Wheelen et. al, 2004*).

IR laid a Vision to raise speed of passenger trains to 160-200 kmph on segregated routes by the year 2020. However, IR's mission statement and quantified objectives, detailing road map specific to achievement of semi-high speed vision, for effective communication to all Railwaymen, Government, Public and other stakeholders have not been mentioned in lucid details.

2.3.8 Trespassing on Railway Tracks

Trespassing on railway tracks is quite common in India as depicted in Figure 2.3. High density of population living along the railway lines with cattle and pedestrians crossing the lines at many locations is a reality. Cultural issues related to discipline and behaviour are also there when there is no physical barrier (*Tayal, 2012*). If the trespassing continue to happen, it will be quite dangerous for semi-high speed train running in that locality. IR does not have provision of platform fences for safety of people on platform. Public announcement and awareness campaigns are necessary before commencing operation of semi-high speed trains. Every station platform on the route of semi-high speed trains ought to provide passenger information display and automatic announcement system for pre-warning passengers waiting on the station platform about train passing through that station at high speed.

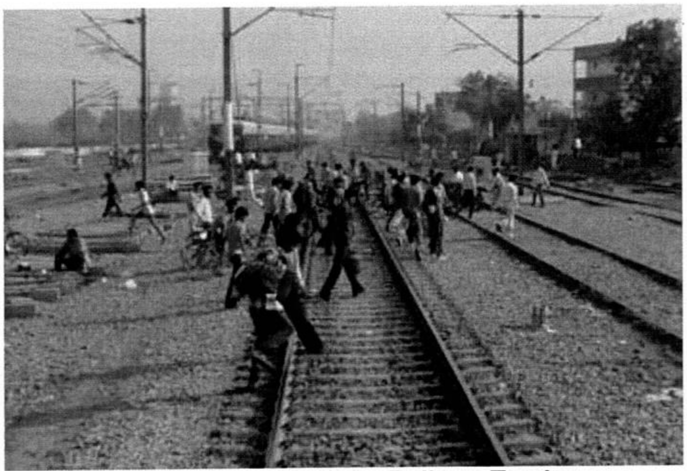


Figure 2.3: Trespassing on Railway Tracks

Besides platform, presently IR has neither the anti-trespass wall nor the fences to protect the tracks on the routes identified for semi-high speed operation. For safe operation of semi-high speed trains, to avoid unnecessary loss of human lives, run over of cattle and loss of punctuality installation of anti-trespass walls or fence is required (*METI, 2013)*.

Thus, in order to achieve semi-high speed train operation on existing routes, following provisions need to be made on identified routes (i) fencing of railway lines to prevent trespassing by people, cattle or any other animals, and (ii) installation of automatic public announcement system at all stations to pre-warn passengers on the platform of passing through stations of semi-high speed trains.

2.3.9 Large Number of Level Crossings

At the end of financial year 2013, IR had 31254 level crossings out of which 18672 (60%) were manned and remaining 12582 (40%) unmanned (*Govt. of India, 2014a*). As on 1st April 2014, population of unmanned level crossings stood at 11563. Unmanned level crossing is a major area of concern (*Govt. of India, 2015a*). Level crossings are safety hazards not only for high speeds but even for the present scenario (*Tayal, 2012*), where almost 50% of the total accidents on IR occur on level crossings. In the year 2012-13, 58 out of total 120 accidents occurred on level crossings (*Govt. of India, 2014a*). IR's ultimate objective is to eliminate all unmanned level crossings by construction of Road Over Bridges (ROB) and Road Under Bridges (RUB) (*Govt. of India, 2015b*). However, trespassing even on manned railway crossing is a common **sight on all over IR's network** as is evident from Figure 2.4.

Figure 2.4 Trespassing on Railway Crossing

Complete fencing of tracks and elimination of level crossings is a must for high speed trains (*Mundrey, 2012*). IR is not permitting any new level crossing as a policy either on exiting lines or new lines/gauge conversion henceforth. It is also eliminating unmanned level crossings by closure, merger with adjacent crossings or provision of a subway, ROB or RUB. However, about 30,000 level crossings still exist on IR network and a good number of these are on the routes identified for upgradation to semi-high speed operation.

Approximately Rs 39000 Crore is required to complete all the ongoing works of constructing Road Over Bridges, Low Height Subways and elimination of all the remaining unmanned Level Crossings (*Govt. of India, 2015a*).

Eliminating level crossing from semi-high speed routes is a major issue that IR needs to address to achieve a speed of 160-200 kmph for passenger trains.

2.3.10 Monitoring of Weather Conditions

For safety considerations, monitoring of weather conditions such as speed of wind, rain fall and water level of rivers etc. need to be monitored closely for semi-high speed train operation. Weather information and warning system is necessary to enable regulation of train speeds to lower and safe levels in bad weather to avoid any possible train disaster in such conditions. Presently, IR does not have any systems for monitoring of weather conditions on its network and needs to make arrangements for the same on those routes that have been identified for operation of semi-high speed train. Weather monitoring systems include water level gauges, one for every bridge to monitor river water level and anemometer (for monitoring wind velocity) and rain gauges, after every 30-40 km distance (*METI, 2013*).

2.3.11 Automatic Train Protection Systems

For semi-high speed train operation, Automatic Train Protection (ATP) based signalling system would be necessary to ensure safe operation. ATP system mitigates the safety risk due to locomotive drivers' error namely passing of signal at danger, over speeding etc., leading to collisions and casualities. Semi-high speed running must have ATP in the entire stretch of all section of identified routes for safety. IR could not be give priority in this area due to paucity of funds (*Govt. of India, 2015a*). A comparison of current signalling systems on IR network and state of art signalling systems used in the world have been shown in the Table 2.3.

Presently, ATP system is limited to sub urban sections of Mumbai, Chennai, Kolkata and Delhi covering EMU rakes. ATP system based TPWS (Train Protection and Warning System) are in trial operation in Agra-Nizamuddin section, and AWS (Auxiliary Warning System) is introduced to the Mumbai suburban section. Most of other sections have either Automatic Block Signalling or Absolute Block Signalling.

For semi-high speed operation, IR needs to either adopt Train Protection Warning System (TPWS) or ETCS (European Train Control System). However, cost of ETCS is very high as compared to TPWS. In ATP, driver follows DMI (Driver Machine Interface), installed in driver cab, for checking the target distance and the target speed. Cab-signalling needs the continuous update of Movement Authority (MA)

Table 2.3: Comparison of Signalling System of IR with Global Benchmark

Signalling and Telecom Elements	Indian Railways	State- of – art / Railways abroad (Global benchmark)
Interlocking systems	(i) Relay based (72%) (ii) EI based (12%) (iii) Mechanical Lever frames (16%)	Electronic Interlocking
Block Working systems	(i) Absolute block (ii) Automatic block signalling (2623 km)	(i) Track circuit block with Automatic signalling. (ii) Communication Based Train Control (iii) CBTC for Rapid Mass Transit.
Train protection systems	(i) AWS (328 km) (ii) ETCS L1(250 km)	Automatic Train Protection
Signals and Movement Authority	(i) Line side Color Light LED (ii) Signals, No cab signalling.	(i) Line side Signals (ii) Cab signalling (iii) Europe: ETCS L2; (iv) China: CTC
Command and Control systems	Distributed, voice commands from train controller	Centralized and Integrated control with automated tools.
Mobile Train Radio Communications (MTRC)	Unsecured, Short range communication system deployed.	Secure, fail-safe and reliable mobile communication system with Save-our-Souls features.
Train detection systems	DC track circuits Axle counters	Axle counters DC track circuits (Relay based Fail Safe)
Level crossings control	Mostly manual control, warning from a fixed distance	Mostly automatic control, warning from a fixed distance

(Source: IR White Paper, Feb 2015)

as in ETCS Level 2 through radio communication between a train and a Radio Block Centre (RBC) or as in the Japanese ATC system through rail between a train and an ATC equipment (*METI, 2013*). IR thus needs to upgrade signalling system on all routes identified for semi-high speed train operation to ATP based system.

2.3.12 Upgradation of Track Infrastructure

The average speed on IR is low even for the trains with maximum permissible speed of 130 kmph. For example, New Delhi- Chandigarh Shatabdi covers a distance of 250 km in 3 hours 15 minutes i.e. at an average speed of 76.9 kmph whereas it could be covered in about 2 hours with an improvement in yards layouts by provision of high speed turnouts, reduced permanent and temporary speed restrictions and advance train control operation for better planning for precedence and crossings (*Mundrey, 2013*).

For higher speeds, elimination of defective welds and rail/weld failures play a significant role in upgradation of track infrastructure. Population of Thermit weld joints need to be brought down drastically by replacing such joints with Flash Butt welds. Mobile Flash Butt welding plants need to be deployed to get rid of defective welds in-situ. Thick Web Switches (TWS) and improved Switch Expansion Joints (SEJ) also need to be installed in big way (*Tayal, 2012*).

TWS is a necessary for high speed routes being technically superior (better service life, less prone to wear, sturdier, require less maintenance) to Over Riding Switch (ORS) commonly used on IR. Long Welded Rails (LWR) are necessary for high speed operation as these help in elimination of fish plated joints and provide continuous path for smooth running. IR has LWR on most of the trunk routes but turnouts in station yards, located at every 8-10 Km, break this continuity. Advance railway systems use swing nose crossings for obtaining gapless track in crossing portion specifically for high speed routes and higher axle load (*Singhal et. al, 2012*).

Speeding up of the passenger trains on IR could be achieved by better yard layouts, adopting high speed turnouts, minimizing time allowance for permanent/temporary speed restrictions, by improving efficiency in track monitoring and maintenance. Existing broad gauge tracks on Class 'A' route of IR are designed for maximum speeds up to 160 Kmph. However, there are few hurdles in achieving even this designed speed of 160 Kmph on the existing network from track side such as (i) sharper curves necessitating imposition of permanent speed restrictions, (ii) vulnerable locations like level crossings, Turnouts, SEJ's etc., (iii) work sites with severe speed restrictions, (iv) existing permanent speed restriction on various sections, (v) maintenance requirements of infrastructure, (vi) alignment compulsions and (vii) slower speeds at entry/exit of yards for negotiation of turnouts (*Gupta, Jan 2012*).

In order to improve speed potential on existing network, realignment of curves is needed to restrict sharpness within permissible limits. Transition length of curves need to be increased to facilitate passing of curves by trains at higher speeds without causing discomfort to passengers.

In nut shell, IR needs to take following actions for upgradation of track infrastructure for semi-high speed operation; (i) replacement of existing Over Riding Switch turnouts with high speed Thick Web

Switch turnouts, (ii) use of swing nose crossings for eliminating fish plated joints at crossings, (iii) use of mobile flash butt welding in place of aluminium thermit welding for joining of rails, (iv) extension of transition curve length for smooth passing of semi-high speed trains on curves, (v) increasing permissible cant deficiency on existing tracks, and (vi) attending weak structures like bridges, culverts etc. and flattening of sharp curves to minimise permanent and temporary speed restrictions.

2.4 Issues in Semi-High Speed Rail

Based on literature review conducted, IR is facing following major issues/challenges in increasing speed of passenger trains to semi-high speed (160-200 kmph) on existing tracks; (i) segregation of passenger and freight trains on major trunk routes due to delayed execution of DFCs planned on golden quadrilateral, (ii) lack of financial resources due to inadequate budgetary support, insufficient internal and extra budgetary resources like PPP etc. and under-recovery of cost in passenger business, (iii) over saturated trunk routes due to slow progress of doubling/quadrupling works, hardly leaving any margin to increase speed of trains on such routes, (iv) non availability of high horse power locomotives, high speed coaches and train sets for semi-high speed operation with desired acceleration, (v) organisational restructuring for efficient project execution, (vi) under recovery of cost in passenger business due to subsidised sub-urban and second class fares, (vii) inadequately defined mission and objectives for semi-high speed vision, laying a clear road map with time bound targets, (viii) trespassing on railway tracks adding to safety hazards in semi-high speed operation, (ix) large number of level crossings impacting safety of high speed operation, (x) monitoring of weather condition, (xi) automatic train protection system based signalling system, (xii) automatic public announcement system on stations, and (xiii) upgradation of track infrastructure.

2.5 Conclusion

IR is one of the largest rail networks of the world. IR's attempts to raise speed of passenger trains started in 1987 when a study was conducted with the help of JICA for Delhi-Kanpur section. However, in the three decades since then, not much progress has been made in raising speed of passenger trains to semi-high speed level (160-200 kmph) although high speed offers several benefits like huge capacity, energy efficacy, boost to economic development etc. There are several issues in implementation of semi-high speed on existing tracks like over saturated capacity utilisation on most of sections on trunk routes leaving no scope for any increase in speed, non-segregation of passenger and freight services, non availability of high speed locomotives, coaches and train sets for semi-high speed operation, inadequately defined mission and objectives, lack of financial resources, rigid organisational structure, no-upgraded track and bridge infrastructure, non availability of ATP based signal system, absence of automatic public announcement system on stations, large number of level crossings and non-fencing of tracks.