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THE CASE FOR DEVELOPING HIGH-SPEED RAIL CORRIDORS IN INDIA

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Executive summary

The operations of the conventional rail system in India are not in sync with the current needs of faster, comfortable and more frequent travel. The Indian Railways (IR) network is so large and complex that upgrading the existing IR network to meet the faster travel demands may take decades. With technical and financial assistance from Japan, India is building its first High Speed Rail (HSR) between Ahmedabad and Mumbai, which is anticipated to be operational by 2030. The development of HSR on the Golden Quadrilateral and its diagonals, about 10,000 km, may boost the capacity of rail transport significantly, as every kilometre of HSR provides about five times the capacity of conventional rail when the HSR capacity utilisation is more than 90%.

This study explains the technological, societal, environmental, and economic reasons for creating HSR corridors as well as how to do it. Chapter 1 provides a brief overview, while Chapter 2 discusses the current state of rail transport services and infrastructure. Since 1950-51, road has dominated passenger transport, while rail passenger traffic has steadily decreased, reaching roughly 5% in 2018-19. The main obstacle for IR to significantly increase traffic on on its network is congestion, particularly in the High Density Network. In order to facilitate freight traffic between Delhi and Mumbai and Delhi and Kolkata, IR has developed the Western Dedicated Freight Corridor and the Dedicated Freight Corridor, respectively. These two arteries of the High Density Network are still congested, nevertheless. In 2016-17 IR announced Mission Raftaar to increase throughput, which would increase the speed between Delhi and Kolkata and Delhi and Mumbai to 160 kmph. Due to several practical challenges, this ambitious mission has not been carried out, except for a few sections. IR also invested between INR 12 lakh Cr. and 13 lakh Cr. between 2014-15 and 2022-23 on a number of areas related to the development of railway infrastructure, particularly the extension of the track by roughly 16,000 km. Nevertheless, this action did not lessen traffic congestion or boost IR throughput or increase the speed of services either. Further, the improvement in rail infrastructure as envisaged in National Rail Plan 2021 is too little and too less ambitious as it proposed increasing the track length in congested sections by about 18,000 km only. The mixed traffic and hence the speed differential because of four types of trains with four different speeds have been affecting the throughput of IR for a very long time now. Chapter 2 also evaluates why the conventional rail tracks cannot be upgraded to 200 kmph so as to become “upgraded HSR,” and it requires massive investment and route realignment in many sections, and hence it is a time-consuming process. The subdued PRS passenger demand is another area due to the information on the probability of confirmation available to the passengers before booking tickets on waitlisting.

Chapter 3 makes a case for developing more HSR corridors in India. India’s per capita GDP PPP (USD) is reasonably on par with HSR pioneer countries. The first HSR is under construction and there is no announcement on the development of future routes of HSR in the years to come. Despite that, India increased its capabilities of the HSR development with the first HSR project with innovation and customisation. There is a clear shift in passenger preferences towards faster and luxurious modes. The rail AC travel between 2005-06 and 2022-23 increased almost 100% more than the non-AC travel. Accordingly, IR also increased the supply of AC coaches. The domestic air travel exceeded AC rail travel in 2017-18, which indicate a need for faster travel. The luxury bus travel which constitutes about 70% of the total omni bus travel was about twice that of rail AC travel in 2024. This indicates that in the absence of rail AC tickets, passengers prefer luxury buses. This chapter also highlighted the costs of various luxury classes, proposed fares for HSR and how the fares of these modes have been on the same order, whereas the end-to-end travel time will be shorter for HSR and Air. HSR can help IR reclaim its ground as the first choice of transport. HSR would create twofold to fivefold capacity compared to the conventional rail. Capacity utilisation of 30% - 40% of HRS is still very good, as the Tokaido Shinkansen, the HSR corridor with maximum patronage and windfall profit so far, utilises just 38% of its maximum capacity. Even a 5% utilisation of HSR capacity would ensure financial viability. India's expertise with semi-HSR with the introduction of the Regional Rapid Transit System to 34 km in the first RRTS corridor of Delhi-Meerut, which can clock a maximum speed of 180 kmph on standard gauge, and the introduction of 66 Vande Bharat trains, which also can clock a maximum speed of 180 kmph on broad gauge would facilitate India to progress to new alignment HSR and upgraded HSR in the years to come.

Chapter 4 elaborates on the benefits that accrue to India with the expansion of HSR. All rail classes with the exception is the 3AC are heavily subsidized. With HSR, 1AC and 2AC passengers in large numbers would move towards HSR thereby saving the subsidy. Shift of passengers from Rail luxury modes towards HSR would provide additional capacity in the Mail/Express trains to accommodate some more sleeper and second-class coaches.

In other HSR countries, the development of HSR has expanded the Urban Agglomeration of enroute cities much beyond what it was there before HSR. Even if some of the HSR corridors get huge patronage, there will be a windfall profit, which can be used to cross-subsidize conventional rail passenger transport. The HSR development to the tune of a few thousand km will create both direct and indirect employment for some millions of man-months. India aims to become a developed economy before 2047, commemorating with the hundred years of independence, and a developed economy should have more than one option for faster travel, and HSR will fulfil this.

Despite spending about INR 15 lakh crore till 2023-24, IR has been unable to show significant progress in its throughput as the spending has been too thin across too many things. The spending on HSR will be targeted spending. The development of HSR will also bring opportunities to manufacture various subsystems of HSR, thereby facilitating Atmanirbhar Bharat. When India becomes the developed nation, the value of time of individuals becomes much more critical, and HSR will facilitate it with substantially reduced end-to-end travel time. India imports about 87% of its crude oil requirements. The electric traction of HSR would decrease the oil vulnerability of India much more compared to aviation turbine fuel used in airplanes. HSR would contribute significantly towards the goal of a net-zero economy for India by 2070.

India has the option of developing the subsequent HSR corridors with indigenous technology at least for some sub-systems, thereby make India self-reliant on HSR technology. The travel by faster and comfortable mode provides dignity of travel to the citizens, which is an integral part of ease of living.

Chapter 5 suggests modifications in the National Rail Plan's (NRP) framework after discussing the HSR corridors recommended by NRP. The initial shortlisting of HSR corridors to be taken up on priority between 2025 and 2035 is based on a gravity model. Minimum ridership of 90 lakh end-to-end passengers in the first year of operation was the main criteria while analysing these HSR corridors. Whether the selected corridors accommodate various holistic criteria was tested again, and then the HSR corridors to be prioritised between 2025 and 2035 were finalised as four major HSR corridors of a distance of 4,705 km. Such a large-scale development of HSR cannot be done by importing technology, and the reasons why India should go for indigenous development of HSR have been explained.

HSR pioneer countries have improved their HSR systems, with the guiding principle of "One size does not fit all." Japan developed HSR on standard gauge with wide-bodied coaches, first with 210 kmph speed. It then gradually improved its technology to reach a maximum speed of 350 kmph, while retaining narrow gauge for its existing conventional rail network. Italy developed "Pendolinos" (tilting trains) for the first time on conventional lines and dedicated lines thereby achieving HSR on upgradation and new alignment. France adopted "mixed HSR" model. Germany adopted a twofold strategy for HSR by upgrading the conventional rail lines to operate at a maximum speed of 200 kmph and developing new HSR systems at a maximum speed of at least 250 kmph. Austria did likewise to achieve a maximum speed of 200 kmph to 230 kmph. To achieve interoperability between its conventional Iberian gauge tracks and newly developed standard gauge HSR lines, Spain developed gauge switching coaches. In addition, Spain also developed tilting trains that could operate at more than 200 kmph on conventional tracks. The European countries took advantage of the same standard gauge that prevails in adjacent European countries and extended their HSR services to cities of other countries. Depending on demand and speed restrictions, they have been operating their HSR anywhere between 200 kmph and 320 kmph while investing considerably in R&D. New HSR corridors completed with the latest technological advancements enabled lower energy consumption. Although European countries and Japan met the HSR requirements, they have been innovating on HSR rolling stock with unabated interest. This indicates that the pioneer countries charted their own course of HSR development based on their needs, capabilities, and circumstances and India should do likewise. The report concludes with the recommendation of setting up the National High Speed Rail Technology Corporation with four tasks: Demonstrate a new HSR system at 250 kmph, demonstrate upgraded HSR system at 200 kmph, develop tilted HSR trains at a speed of 200 kmph and radially aligning self-steering bogies for freight trains

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Abbreviations

ABS	Automatic Block Signaling
ADB	Asian Development Bank
ATO	Automatic Train Operation
ATP	Automatic Train Protection
ATS	Automatic Train Supervision
BIM	Building Information Modelling
BPKM	Billion Passenger Kilometer
CAGR	Compound Annual Growth Rate
CCMS	Coach Condition Monitoring System
CORS	Continuously Operating Reference Station
CTC	Centralized Traffic Control
DBFOT	Design, Build, Finance, Operate and Transfer
DFC	Dedicated Freight Corridor
DPR	Detailed Project Report
EDFC	Eastern Dedicated Freight Corridor
EIRR	Economic Internal Rate of Return
EMU	Electric Multiple Unit
ETCS	European Train Control System
EV	Electric Vehicles
FIRR	Financial Internal Rate of Return
GCT	Generalised Cost of Travel
GDP	Gross Domestic Product
GoI	Government of India
GQ	Golden Quadrilateral
GSRTC	Gujarat State Road Transport Corporation
HAM	Hybrid Annuity Model
HDN	High Density Network
HSRIC	High Speed Rail Innovation Centre
HUN	High Utility Network
HSR	High Speed Rail
ICF	Integral Coach Factory
IISC	Indian Institute of Science
IIT	Indian Institute of Technology
IR	Indian Railways
IRC	Item Rate Contract
IRCTC	Indian Railway Catering and Tourism Corporation
JARTS	Japanese experts of Japan Railway Technical Service
JICA	Japan International Cooperation Agency
LHB	Linke-Hofmann-Busch
LSS	Limited Stop Service
MoCA	Ministry of Civil Aviation
NCR	National Capital Region
NHSRCL	National High Speed Rail Corporation Limited
NHSRTC	National High Speed Rail Technology Corporation
NIP	National Infrastructure Pipeline
NIT	National Institute of Technology

NRP	National Rail Plan
O-D	Origin-Destination
PKM	Passenger Kilo Meter
PPP	Purchasing Power Parity
PRS	Passenger Reservation System
R&D	Research and Development
RRTS	Regional Rapid Transit System
SPV	Special Purpose Vehicle
SRTC	State Road Transport Corporation
TCAS	Train Collision Avoidance System
TCO	Total Cost of Ownership
TERI	The Energy and Resources Institute
TOD	Transit Oriented Development
ToT	Transfer of Technology
UA	Urban Agglomeration
UIC	International Union of Railways
USO	Universal Service Obligation
UTS	Unreserved Ticketing System
VB	Vande Bharat
VCF	Value Capture Financing
VGF	Viability Gap Funding
WDFC	Western Dedicated Freight Corridor

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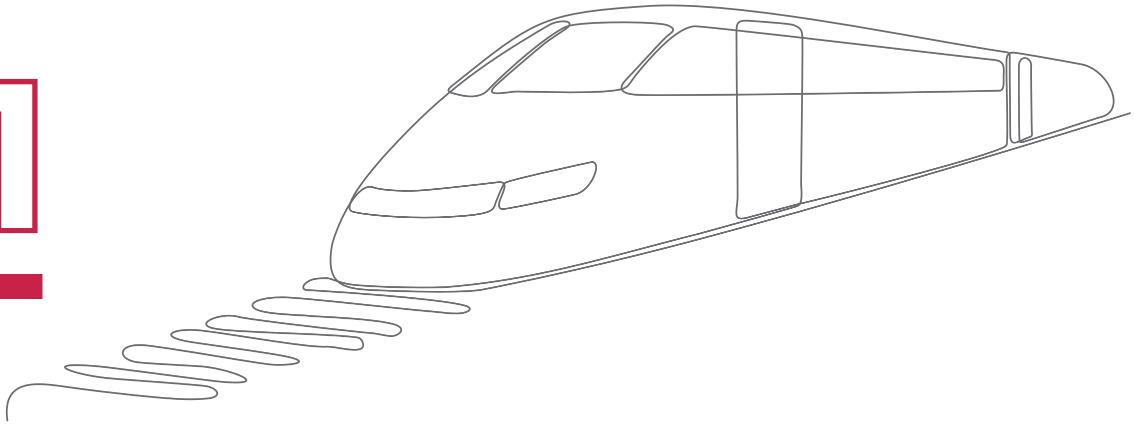
CHAPTER 01



Introduction

The first High Speed Rail (HSR) project between Ahmedabad and Mumbai will cover 508 km and will use the Standard Gauge used in Shinkansen trains in Japan. Twelve stations, including the terminals for arrivals and departures, will be part of it. Since 2017, Japan has been providing support to the extent of 81% of the entire project cost for the first HSR project, which is essentially on technology transfer on civil infrastructure, station development, rails, electric traction, rolling stock, signal and telecommunication and central monitoring system that are compatible with Indian conditions (NHSRCL, 2024). The 55-kilometer HSR route between Surat and Bilimora is expected to be operational by July or August 2026 (PIB, 2024, February 23). The Gujarat portion of 352 km (Sabarmati-Vapi) is expected to be commissioned by August 2027 (Law, A., 2024, February 4).

During the first year of operation, 35 services will be offered in a single direction. E5 Shinkansen trainsets will be utilized as the rolling stock; they have ten carriages and can accommodate about 690 passengers in three different classes: Standard (3x2 seats), Business (2x2 seats), and First or Grand Class (2x1 seats), providing 17,900 passenger seats in one way direction and 35,800 passenger seats daily in two-way direction. In peak hours, there will be three trains per hour, and in non-peak hours, there will be two trains per hour in each direction (NHSRCL, n.d.a). To do this, 24 rakes (including standby) will be utilized (NHSRCL, 2021, June). This is as per the Detailed Project Report (DPR) prepared by Japan International Cooperative Agency (JICA) considering the first year of operation is 2024. However, when the commissioning is delayed by few more years, the demand for HSR rolling stock would increase substantially.

At the end of the 10th year of operation, 11 more rakes with 16 coaches will be added and will provide a daily two-way capacity of 63,400 passenger seats. At the end of the 20^{th} year of operation, 13 more rakes will be added along with 16 coaches, and will provide a daily two-way capacity of 113,600 passenger seats. At the end of the 30^{th} year of operation, 27 more rakes will be added along with 16 coaches, and will provide a daily two-way capacity of 185,800 passenger seats (NHSRCL, n.d.a).

There will be two categories in the first HSR service: Rapid HSR in 2 hours and 4 minutes with stoppages at Vadodara and Surat, and HSR in 2 hours and 35 minutes with stoppages at all the stations.

Before National High Speed Rail Corporation Limited (NHSRCL) was formed, Indian Railways (IR) employed various consultancy firms to identify several corridors between 2008 and 2020 and producing pre-feasibility and feasibility reports on the same. These corridors are given below:

- Mumbai-Pune-Hubbali-Bengaluru-Tirupati-Chennai 1368 km
- Hyderabad-Vijayawada-Chennai 679 km
- New Delhi-Agra-Lucknow-Allahabad-Varanasi-Patna 988 km
- Delhi-Jaipur-Ajmer-Jodhpur-Ahmedabad-Vadodara-Surat-Mumbai 1410 km
- Delhi-Aligarh-Lucknow-Varanasi-Patna-Dhanbad-Asansol-Kolkata 1474 km
- Delhi-Panipat-Karnal-Ambala-Chandigarh-Ludhiana-Phagara-Jalandar-Amristsar 465 km
- Chennai-Bengaluru-Coimbatore-Ernakulam and Thiruvananthapuram and have a branch line to Mysore 1060 km.

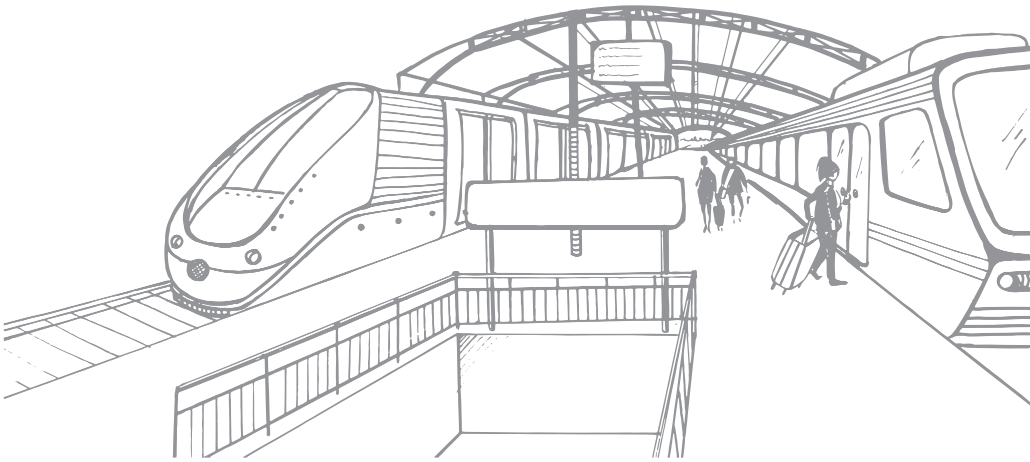
Then, with the assistance of consulting firms over the past few years, NHSRCL prepared every component of the DPR for the corridors that the National Infrastructure Pipeline (NIP) had identified. These components were then combined to create a comprehensive DPR that included all dimensions for the following corridors (NHSRCL, 2021).

- Delhi-Agra-Lucknow-Varanasi 865 kms
- Varanasi-Patna-Kolkata 760 kms
- Delhi-Jaipur-Udaipur-Ahmedabad 886 kms
- Delhi-Chandigarh-Ludhiana-Jalandhar-Amritsar 459 kms
- Mumbai-Nashik-Nagpur 753 kms
- Mumbai-Pune-Hyderabad 711 km
- Chennai-Bengaluru-Mysore 435 km

Although IR in principle emphasized the need to develop about 10,000 km of HSR routes across India and begun constructing the first HSR between Ahmedabad and Mumbai, IR is yet to decide on the next HSR corridors to be developed. To emphasize the need to take up the next few HSR corridors between 2025 and 2035, The Infravision Foundation decided to come up with the research paper titled "The Case for Developing High-Speed Rail Corridors in India". The key aspects of the research paper are as follows:

- Status of rail transport infrastructure and services
- The case for HSR development
- Benefits of expanding the HSR network in India
- Roadmap for HSR futures

CHAPTER 02



Status of Rail Transport Infrastructure And Services

Status of Rail Transport Infrastructure and Services is discussed in this chapter with the following themes.

- Passenger traffic in India
- Congestion in IR
- Mixed Traffic
- Infeasibility of upgrading rail infrastructure
- Subdued PRS passenger demand

2.1 Passenger traffic in India

The overall growth of passenger transport between 1950-51 and 2023-24 is as shown in Table 1. It is evident that the share of rail transport in the overall passenger transport has been declining since 1950-51 for various reasons.

Table 1 Passenger traffic in India

Year	Traffic (BPKM)***				Share (%)		
	Railway	Road	Air	Total Traffic	Railway	Road	Air
1950-51*	67	31	0.24	98	68.04	31.71	0.25
1960-61*	78	81	0.58	159	48.8	50.83	0.36

Year	Traffic (BPKM)***				Share (%)		
	Railway	Road	Air	Total Traffic	Railway	Road	Air
1970-71	118	210	1.56	330	35.83	63.70	0.47
1980-81	209	542	4	754	27.65	71.83	0.52
1990-91	296	1671	7	1974	14.98	84.66	0.36
2000-01	457	2076	12	2545	17.96	81.56	0.48
2010-11	979	8409	52	9440	10.37	89.08	0.55
2018-19	1157	22582	135	23874	4.85	94.59	0.57
2019-20	1051	25,199	137	26,387	3.98	95.5	0.52
2020-21	231	NA	53				
2021-22	590	NA	82				
2022-23	959	NA	132				
2023-24	NA	NA	148				
CAGR 1950-51 to 2010-11****	4.580	9.790	9.380	7.910			
CAGR 2010-11 to 2018-19**	2.120	13.140	12.620	12.300			

*The PKM flown by air is for the year 1951-52 and 1961-62 respectively in lieu of 1950-51 and 1960-61

**The CAGR was taken up to 2018-19 as the Covid pandemic distorted the passenger traffic data till at least 2021-22

*** BPKM refers to Billion Passenger Kilo Meter an one PKM corresponds to one passenger travelling one Kilo Meter distance

****CAGR refers to Compound Annual Growth Rate

Note:
For Road and Rail data up to 2000-01, the reference is The Hindu Centre (n.d.)
For Road data for 2010-11 and 2018-19, OGD Platform India (n.d.)
For Air up to 2000-01, CMIE (March 2011), For Air data between 2018-19 and 2023-24, DGCA (n.d.)

Rail data is from IR (2020), IR (2021), IR (2022) and IR (2024)

Source: Author's calculations based on The Hindu Centre (n.d.), OGD Platform India (n.d.), CMIE (March 2011) and DGCA (n.d.), IR (2020), IR (2022) and IR (2024)

The observations from Table 1 are as follows:

- The share of rail passenger transport declined decade after decade since 1950-51 and reached 10.37% in 2010-11. The share of domestic air passenger transport increased from 0.24% in 1950-51 to 0.55% in 2010-11. This was aided by the opening up of skies to private players in 2004 coupled with development and continued expansion of Delhi, Mumbai, Bengaluru and Hyderabad airports on Public Private Partnership basis removing the supply side constraints of air passenger transport.
- With ever declining rail passenger transport share and not so rapidly increasing domestic air traffic share (due to its low base), the road passenger transport share started gaining dominance in 1960-61 and reached 89.08% in 2010-11. Also, the phenomenal growth of National Highways, Expressways and other roads by various means such as DBFOT (Design Build Finance Operate and Transfer), Annuity, HAM (Hybrid Annuity Model) and IRC (Item Rate Contract) since 1998 removed the supply side constraints of road passenger transport. The road cess collected on the fuel and the revenue from tolling also gave a boost for more allocation of funds for road development. The growth of multi-axle AC buses and personal cars since the beginning of 21st century facilitated to meet the demand of passenger transport.

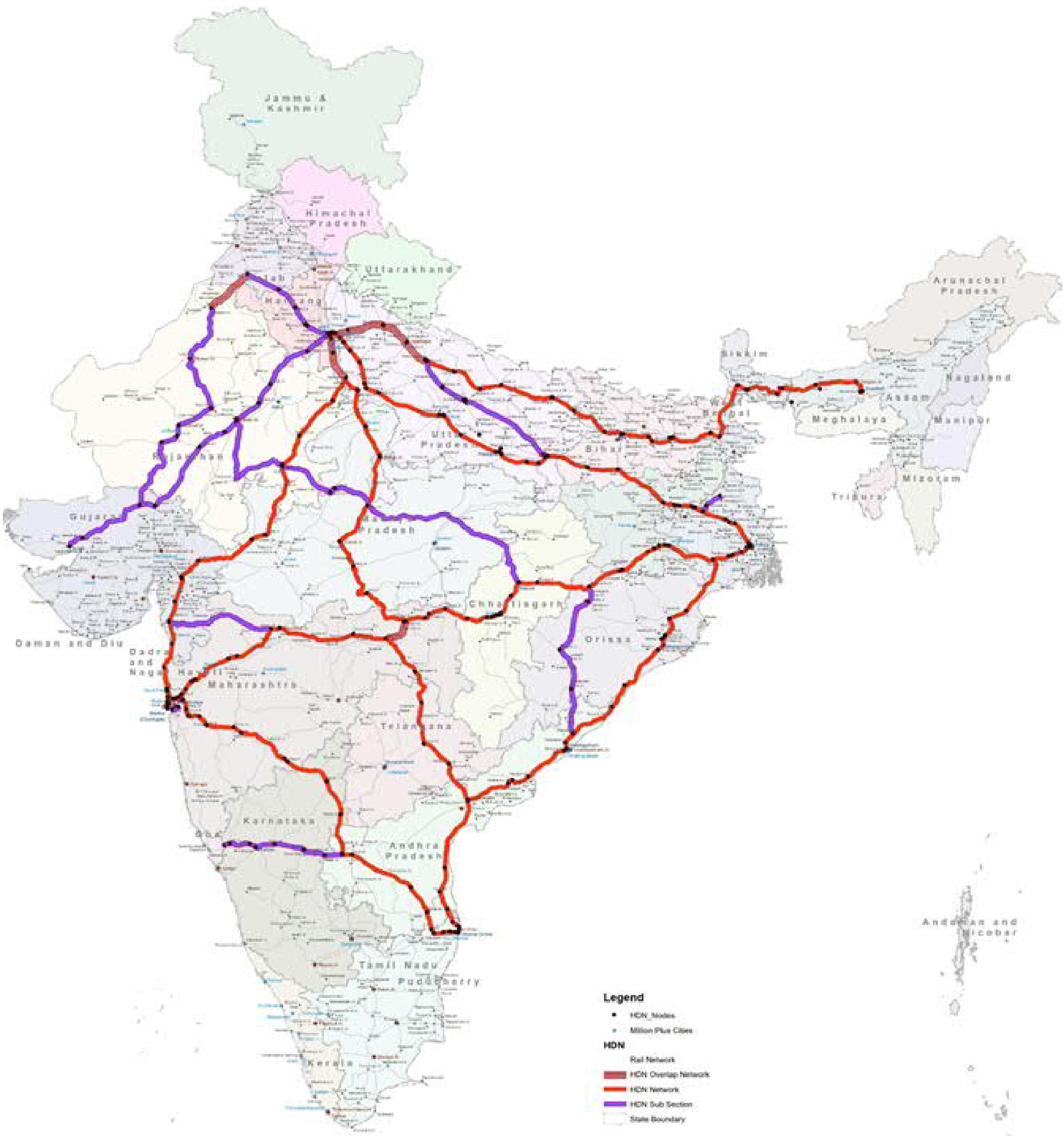
- All three modes were impacted by the COVID pandemic in 2020-21 and 2021-22 which resulted in lower passenger traffic. Subsequently, although all the three modes picked up the traffic, air has picked up much faster whereas rail has been slower.

IR has adopted various measures to improve the throughput of railway network as discussed in the following sections

2.2 Congestion in IR

IR has a total route length of 68,584 km and a total running track length of 1,06,493 by FY 2022-23. IR identified seven High Density Network (HDN) routes shown in Figure 1.

Figure 1 HDN Routes of IR



Source: *IR (2021).*

The HDN routes along with their capacity utilization as shown in Table 2. The HDN consists of 10,969 km, connecting the golden quadrilateral and its diagonals, plus some additional corridors, which are extremely congested. About 80% of the 10,969 km HDN is now functioning at capacity utilization levels above 100%, with the remaining 18% working between 70% and 100%.

Table 2 HDN with existing capacity utilization

HDN Description	Existing Capacity Utilization (%)			
	0%-70%	70%-100%	100%-150%	>150%
HDN-1 Delhi-Howrah	0	18	81	1
HDN-2 Howrah-Mumbai	1	7	80	12
HDN-3 Mumbai-Delhi	0	12	83	5
HDN-4 Delhi-Guwahati	0	27	46	27
HDN-5 Delhi-Chennai	6	2	83	10
HDN-6 Chennai-Howrah	0	6	88	6
HDN-7 Chennai-Mumbai	5	38	55	2

Source: PDL (2015)

IR has planned and partly executed various plans to ease congestion and to improve the flow of traffic so far as listed below:

- Dedicated Freight Corridors
- Mission Raftaar
- Rail infrastructure augmentation by means of increased investment

In the following sections, the efficacy of the measures that are planned and executed to ease congestion is discussed in detail.

2.2.1 Dedicated Freight Corridors

Commissioning of EDFC (Eastern Dedicated Freight Corridor) and WDFC (Western Dedicated Freight Corridor) has not yielded any significant relief from congestion so far.

About two-thirds of IR's train infrastructure and human resources are used for passenger services, while they only account for one-third of IR's overall revenue. Despite consuming roughly one-third of IR's rail infrastructure and personnel resources, the freight services account for two-thirds of IR's overall revenue. The routes used by both services are shared by mixed traffic.

Among all HDN, the Delhi-Kolkata (HDN1, primary route, 1463 km) and Delhi-Mumbai (HDN3, 1387 km) routes alone make up roughly 2850 km of the 10,969 km HDN. Recognizing the need for dedicated freight corridors along these most congested routes, Government of India (GoI) chose to create WDFC and EDFC under the auspices of Dedicated Freight Corridor Corporation of India Limited (DFCCIL) in 2007. Most of the freight business was moved from conventional rail to DFC with the full commissioning of EDFC and 80% commissioning of WDFC. It was anticipated that this would enhance the capacity for passenger train operations on these routes by roughly 50%.

Moving around one-third of the current load to DFC could not reduce congestion in some HDN1 and HDN3 sections, where 82% and 88% of the sections, respectively, have been operating at a capacity utilisation of over 100% (IR, 2021). For example, adding two more lines of DFC to the four-line network will lower the load factor to 120% where it was 180% earlier. Additional passenger services can be added only if the load factor is less than 100%. Furthermore, a network's weak links are its congested sections, which will act as a bottleneck to keep the IR network's overall throughput from increasing for both passenger and freight services. Furthermore, the feeding traffic for DFC may come from traditional rail infrastructure, thus even with the DFCs, not all freight traffic will switch to DFC.

2.2.2 Mission Raftaar

To meet the goal of doubling the average speed of goods trains and raising the average speed of Superfast, Mail, and Express trains by 25 kmph in the next five years, IR announced "Mission Raftaar" in 2016. However, the implementation of this mission has been extremely slow.

In the Railway Budget 2016-17, IR announced Mission Raftaar for the two HDN1 and HDN3 circuits in order to alleviate this congestion. HDN1 and HDN3 comprise just 4.17% of the 68,426 km of route length of IR and even if they are upgraded to 160 kmph in their entirety the other HDN of IR routes will remain unattended. Only about 500 km of the 2850 km of HDN1 and HDN3 have been upgraded to run at 160 kmph after the announcement of Mission Raftaar in 2016-17.

In October 2016 IR announced that the Ghaziabad-Allahabad-Mughalsarai Route would be taken up on a priority basis as a part of Mission Raftaar. Trains in this section now run with improved average speed (PIB, 2016). The maximum speed of the Mumbai-Ahmedabad section (except the Mumbai suburban section of Church Gate-Virar, which continues to run at 110 kmph) has been increased to 160 kmph in March 2024 by various measures such as the removal of some permanent speed restrictions, rails of 52 kg per meter replaced by 62 kg per meter, strengthening of bridges, sleeper density increased so tracks stay firm when trains run at 160 kmph, manned level crossing gates replaced with rail over bridges, upgrade of signalling and traction power systems, and Train Collision Avoidance System (TCAS) in trains where the loco pilot gets a signal in his cab.

The Comptroller and Auditor General of India (CAG) report tabled in the 2022 Budget session pointed out that Mission Raftaar had not advanced. In response to the CAG, IR stated that Mission Raftaar is not a stand-alone project and that it is impossible to quantify the total amount of money allocated and used for it. Furthermore, IR defended the increase in the average goods train speed from 23.7 kmph to 41.2 km/h from the fiscal year 2016-17 to the fiscal year 2020-21. However, IR cancelled numerous passenger routes during the Covid-19 pandemic (PIB, 2022). When regular passenger services began, the average speed of the cargo trains dropped to around 25 kmph. Both the goal of doubling the speed of freight services and the goal of increasing the speed of passenger services by 25 kmph were not met. The average speed of freight or mail/express trains did not change between the announcement of Mission Raftaar in 2017 and 2024. IR admitted that Mission Raftaar cannot function in mission mode due to a number of barriers to speeding up HDN corridors. For instance, the speed of the portion with bridges cannot be raised if the bridges do not permit greater speeds as required by Mission Raftaar. It is clear that IR will take much more time to enhance the maximum speed of its network unless it is done with the speed at which the electrification of tracks has been done. However, unlike the electrification of tracks, Mission Raftaar is a multi-dimensional project and involves large-scale coordination.

IR categorized their sections into various groups based on the maximum permissible speed and to carry out maintenance based on the maximum speed assigned for each category (PDL 2024, February 07, b):

- Group 'A', with speed of up to 160 kmph
- Group 'B' with speed of up to 130 kmph
- Group 'C' consists of the suburban sections of Mumbai, Delhi, Chennai, and Kolkata.
- Group 'D' with speed up to 110 kmph

Neither the average speed of the passenger nor freight services increased substantially over the years, which indicates that the above categorisation as per speed restrictions continues even now. This implies that Mission Raftaar did not take off on a large scale. Moreover, in some of the sections, the maximum speed was reduced to 130 kmph from 160/150 kmph, as in the section of Palwal to Agra (Rail Journal, 2024), contrary to the objective of Mission Raftaar.

It is nearly impossible for the IR to perform augmentation work, such as smoothening curves, upgrading them to automatic signalling, replacing traction equipment, or repairing bridges, without shutting down the lines for a considerable amount of time.

It is also not possible to perform speed enhancement work in the traditional train corridors without alternative rail lines for the transportation of passengers and freight, as this will significantly impair network operations. When alternative rail routes, such as DFC freight transport and HSR passenger transport, are available, it is ideal to carry out the work to increase the capacity of the current conventional lines. The government may offer discounted prices to HSR passengers during the speed augmentation work of the conventional train network, allowing even low-income segments to use the HSR system.

2.2.3 Rail infrastructure augmentation by means of increased investment

The central government invested about INR 13,00,000 Cr. between 2014-15 and 2022-23, which was spent on various capital expenditures. But increase in passenger services has not been commensurate with the investment made in IR. Table 3 and Table 4 show the input and output metrics of IR between 2014-15 and 2022-23.

Table 3 Input matrices of Indian Railways

Input in track infrastructure

	A	B	C	D	Ratios	
Year	**CapEx / Plan Investment (INR Cr)**	**Route Length (km)**	**Track Length (km)**	**Electrified route length (km)**	**C / B**	**D / C**
2013-14	53,989	65,426	89,919	39,661	1.37	0.44
2014-15	65,445	65,600	90,803	41,038	1.38	0.45
2015-16	96,181	66,252	92,084	43,357	1.39	0.47
2016-17	1,09,935	66,918	93,902	48,239	1.4	0.51
2017-18	1,01,985	66,935	94,270	51,242	1.41	0.54
2018-19	1,33,377	67,415	95,981	59,142	1.42	0.62
2019-20	1,48,064	67,956	99,235	67,452	1.46	0.68
2020-21	1,55,181	68,103	1,00,866	74,534	1.48	0.74
2021-22	1,90,267	68,043	1,02,831	82,654	1.51	0.8
2022-23	2,45,300	68,584	1,06,493	92,358	1.55	0.87
2023-24	2,60,200					
Infrastructure added* between 2013-14 and 2022-23 (Units)		3,158	16,574	52,697		
Growth (%)**		4.83	18.43	132.87		

*between 2013-14 and 2022-23 (km)
**between 2013-14 and 2022-23

Input in Rolling Stock (Units)

	Locomotives			Coaching Stock			
Year	**Diesel**	**Electric**	**Total**	**Passenger carriages**	**EMU/ DMU/ DHMU***	**Other coaching vehicles**	**Wagons**
2013-14	5,633	4,823	10,456	50,194	9,371	6,792	2,52,833
2014-15	5,714	5,016	10,730	51,798	9,725	7,000	2,54,018
2015-16	5,869	5,214	11,083	53,140	10,210	6,704	2,51,295
2016-17	6,023	5,399	11,422	53,638	10,617	6,699	2,77,992
2017-18	6,086	5,639	11,725	54,059	11,246	6,499	2,79,308

	Locomotives			Coaching Stock			
Year	**Diesel**	**Electric**	**Total**	**Passenger carriages**	**EMU/ DMU/ DHMU***	**Other coaching vehicles**	**Wagons**
2018-19	6,049	6,059	12,108	55,258	12,315	6,406	2,89,175
2019-20	5,898	6,792	12,690	57,121	13,234	6,611	2,93,011
2020-21	5,108	7,587	12,695	58,778	12,956	7,949	3,02,624
2021-22	4,747	8,429	13,176	65,253	11,984	10,159	3,18,883
2022-23	4,756	9,565	14,321	66,106	11,664	11,139	3,15,791
Infrastructure added** between 2013-14 and 2022-23 (Units)	-877	4,742	3,865	15,912	2,293	4,347	62,958
Growth (%)***	-15.57	98.32	36.96	31.7	24.47	64.00	24.9

*Electric Multiple Unit/Diesel Multiple Unit/ Diesel Hydraulic Motor Unit
**between 2013-14 and 2022-23 (Units)
***between 2013-14 and 2022-23 (Units)

Table 4 Output matrix of Indian Railways

Year	BPKM	Revenue earning TKM (Billion)	Fuel expenses (INR Cr.)
2013-14	979	667	29,235
2014-15	1,147	683	28,766
2015-16	1,143	656	13,036
2016-17	1,150	621	11,949
2017-18	1,178	693	14,925
2018-19	1,157	739	16,565
2019-20	1051	708	14,050
2020-21	231	720	7,285
2021-22	590	872	10,362
2022-23	959	960	19,228
Output between 2013-14 and 2022-23 (units)	-20	293	-10007
Growth (%)	-2.04	43.93	-34.23

Source: Author's calculations based on IR (2012), IR (2014), IR (2016), IR (2018), IR (2020), IR (2022), and IR (2024)

Though the output is not commensurate with the huge investment made by the central government, it had a significant impact on the functioning of IR. There have been both positive and negative implications as listed below:

(i) Positive implications

- 1926 train services were introduced in during the period 2014-15 to 2023-24 to cater to the needs of passengers.
- The number of AC seats/berths increased from 3.52 lakh in 2010-11 to 13.03 lakh in 2022-23, whereas the second-class seats increased from 28.44 lakh to 34.17 lakh (IR, 2012 and IR, 2024). In terms of coaches, two-thirds of the coaches constitute non-AC coaches, and one-third constitute AC coaches (PDL, 2024, July 24, a).
- With concerted effort, IR has achieved about 94% railway electrification in February 2024 (PIB, 2024, February 02). IR is on the verge of reaching complete electrification by FY2025-26. The investment made in electrification resulted in fuel savings of about 34% (INR 10000 Cr) yearly despite the increase of freight traffic by 34% and passenger traffic remaining almost the same. As electric traction becomes the norm, the energy expenses of IR have been under control, not affected by the variations in diesel prices, and that is why IR has been able to maintain less than a 100% operating ratio over the years (except for 2021-22), despite the implementation of Seventh Pay Commission recommendations to its 13 lakh employees and 13 lakh pensioners.
- IR invested INR 1,77,332 Cr. on safety works that include maintenance of Permanent Way & Works, Maintenance of Motive Power and Rolling Stock, Maintenance of Machines, Road Safety LCs and ROBs/RUBs, Track Renewals, Bridge Works, Signal & Telecom Works and Workshops including Production Units and Misc. expenditure on Safety between 2014-15 and 2023-24 against INR 70,273 Cr. on the same between 2004-05 and 2013-14.
- Due to the investment in the upkeep of rail infra-assets on multiple fronts, the consequential train accidents reduced. From 2004-05 to 2013-14, there were 1711 accidents, 904 deaths, and 3155 injuries. From 2014-15 to 2023-24, there was a reduction in all the numbers, with 678 accidents, 748 deaths, and 2087 injuries. (PDL, 2024, August 07, b) and (PDL, 2024, August 07, a).
- Between 2014 and 2024, IR produced 36,933 Linke-Hofmann-Busch (LHB) coaches as opposed to 2,337 between 2004 and 2014, which lessened the number of fatalities and injuries sustained in train accidents. About 56% of the approximately 66,000 passenger carriages are LHB coaches (PDL, 2024, August 07, b).
- By adding 3,10,238 bio-toilets between 2014 and 2024 compared to 9,587 bio-toilets between 2004 and 2014, IR also accomplished cleanliness in the railway ecosystem with the significant investment. IR installed bio-toilets in all their coaches, each of which has four restrooms (PDL, 2024, August 07, b).
- Divyaang-friendly carriages with wheelchair parking spaces, broader berths, wider cabins, and wider entrance doors are available on almost all Mail/Express trains. Accessible parking, foot overbridges with ramps and elevators, lower height ticket kiosks and help booths, Braille signage, tactile pathways for the blind, entry ramps, and restrooms for improved Divyaang accessibility are examples of stations that are Divyaang-friendly (PDL, 2024, August 07, b).
- More comfortable seats and accommodations for Passenger Reservation System (PRS) passengers resulted from the manufacturing and installation of more AC

coaches, which also increased IR's revenue and investment cost. The fact that IR made INR 63,417 Cr. for 959 BPKM in 2022-2023 as opposed to INR 42,190 Cr. for 1147 BPKM in 2013-14 (IR, 2016) and IR, 2024, illustrates this.

(ii) Negative Implications

- On expected lines, the route length has increased only by about 5% (additional route km of 3158 km) between 2014-15 and 2022-23, as IR faces major congestion on the HDN, and the focus of IR is to increase the running tracks on HDN. Although the track length has increased by about 16,574 km, it did not result in a significant increase in passenger traffic between 2014-15 (1147 BPKM) and 2022-23 (959 BPKM). During non-pandemic times, the maximum passenger traffic IR witnessed was in 2017-18 at 1178 BPKM. This indicates that neither the speed of passenger services nor the passenger traffic can increase significantly by adding tracks to the conventional rail under mixed traffic conditions. The dedicated HSR may be the best available option to provide faster and more comfortable passenger connectivity between cities.
- By 2022-2023, IR should have enhanced its throughput in terms of higher speed and passenger and freight traffic due to the approximately 16,500 km increase in running track length (as indicated in Table 3) and electrification of up to 87%. Goods trains reached 45 kmph during the Covid era, when passenger trains were drastically cut. However, the average goods train speed dropped to roughly 25 kmph, the pre-Covid speed, after passenger train services restarted. Despite the fact that moving between tractions with substantial electrification—whether for passenger services or freight trains—no longer requires changing traction, the IR has not been able to utilise this to boost throughput.
- Between 2014-15 and 2023, the number of passenger carriages rose by almost 32% as a result of the greater use of PRS AC coaches compared to second-class coaches. Nevertheless, the demand was not satisfied despite this. For this reason, air travel between cities and AC buses are growing exponentially. Due to limitations including platform length and siding concerns, IR infrastructure may only run a maximum of 24 coaches, which may include 22 passenger carriages. Considering this, IR has very little room to satisfy the needs of passengers on intercity AC buses and airplanes. However, it is IR's duty to provide enough coaches to serve the middle-income and lower-income groups that favour sleeper coaches. When the HSR network is developed, it will pull the AC rail, AC bus, and air passengers to the HSR, leaving enough scope for IR to add more sleeper coaches to meet the middle and lower-income groups.
- The central government spent INR 13 lakh Cr. between 2014-15 and 2022-23 on adding new routes to the existing IR network, additional tracks on the existing network, electrification of routes, adding rolling stock, upgrading of signalling systems, construction of new rolling stock factories, conversion of all unmanned crossings to manned crossings, and construction of ROB/RUB. This essentially resulted in an increase in revenue-earning freight transport in terms of tonne-km by 44% between 2014-15 and 2023-24. Indian Railways has been earning about INR 1.6 for every Rupee spent on freight traffic, whereas it has been earning only 41.4 Paisa for every Rupee spent on passenger services. So, as in the past, the increased spending on

infrastructure in the future will be utilised by IR to increase its freight business rather than cater to the passenger business. IR's operating ratio, which has been in red for many years now, needs to improve, and the known method for IR officials is to focus more on freight traffic.

- Most of the allocation was spent on works that remained a backlog for many decades, such as electrification, safety aspects, maintenance of infrastructure and rolling stock, additional lines on extremely congested routes, and the purchase of new rolling stock (Ramakrishnan, 2023). Although this spending by IR is necessary to overcome the huge infrastructure backlog that has been piling up for many decades, this huge spending has not produced outcomes so far.

(iii) NRP 2021's rail infrastructure Improvement plan is inadequate

Among High Density Network (HDN) routes, 177 sections covering a length of 8,299 route km (75% of total HDN route km) have more than 100% capacity utilization. To reduce capacity utilisation to 100% or less, 71 projects of doubling/multi-tracking/bypass line, covering a length of 5,531 km costing about INR 88,179 Cr., have been recommended by NRP 2021.

Among High Utilized Network (HUN) routes, 175 sections covering a length of 8,665 route km (37% of total HUN route km) are having more than 100% capacity utilization. 117 projects of doubling/multi-tracking/bypass line covering a length of 13,093 km costing about INR 1.65 lakh Cr. over HUN routes are planned, sanctioned, or under execution or executed (PDL, 2023, August 09).

The technique employed by the NRP is sectional, i.e., if a congested section that represents an essential part of one or more routes is provided with additional tracks, it would lower the congestion to a manageable level. The impression that we get from the NRP's recommendation is that if 5531 + 13,093 = 18,624 of running track length is created along with automatic signalling (Train Collision Avoidance System (TCAS) + Automatic Block Signalling (ABS) + Centralised Traffic Control (CTC)) by 2050, the congestion will disappear. If IR traffic has to catch up with the unmet demand of the last four decades and prepare itself for the demand that accrues in the next three decades leading to Viksit Bharat, the rail infrastructure augmentation plan given by the NRP and as planned by IR for the next three decades will be inadequate.

2.3 Mixed Traffic

The main problem with the conventional rail infrastructure is that its carrying capacity is limited by various factors. One key factor is mixed traffic. The order of precedence for the right of way in IR has been Premium trains first, followed by Mail/Express trains, Ordinary trains and finally Freight trains. As a consequence, the premium trains run at an average speed of 65 kmph - 98 kmph, Mail/Express trains run at an average speed of about 55 kmph, ordinary trains run at an average speed of 35 kmph and freight trains run at a speed of 25 kmph.

Sectional speed over 10981 route km covering the Golden Quadrilateral (GQ) & Diagonal routes and other 'B' routes has been raised to 130 kmph (PDL, 2024, February 07, b), which means trains on these routes can operate at an average speed of about 100 kmph. But even on these sections, the premium trains have been operated only at an average speed of 65 kmph to 98 kmph.

The case in point is the Vande Bharat (VB) train. Although IR introduced 66 VB trains as of September 30, 2024 the average speed is nowhere close to the trial run speed of 180 kmph. The average speed of VB trains as per IR was 84.48 kmph in 2021-22 and 81.38 kmph in 2022-23 (BS, 2023, April 17). It may be even lower in 2023-24 as many new VB trains were introduced on Origin-Destination (O-D) pairs that did not support higher maximum speeds. Only New Delhi-Varnasi, Ahmedabad-Mumbai Central, and Rani Kamalapati (Habib Ganj)-Hazrat Nizamuddin VB trains run at an average speed of 90 kmph or above. Few trains like the Coimbatore-Bangalore Cantonment VB train, run at an average speed of 58 kmph. All other VB trains operate at an average speed of 60 kmph-89 kmph.

The VB train has the capability to run at a maximum speed of 180 km with much better stability than loco-hauled premium trains like the Shatabdi and Rajdhani, if the infrastructure supports such high speed. Although the loco-hauled LHB AC coach Shatabdi train can also run at a maximum speed of 160 kmph if the rail infrastructure supports the same, the stability, acceleration, deceleration (due to distributed load), and gangway between coaches (which makes them a train set) in the VB trainset should allow the VB train to run at a higher average speed than the loco-hauled LHB AC rake. The VB train costs about 50% more than the loco-hauled LHB AC coach Shatabdi train of the same capacity, and the passengers also pay about 30% more than Shatabdi to travel in the VB train; the incremental time savings is only about 10% on average.

The upgrade of Mumbai-Ahmedabad rail infrastructure to run trains at a maximum speed of 160 kmph between Virar and Mumbai is expected to reduce the travel time of the VB train from the earlier travel time of 5 hours and 35 minutes to about 5 hours and 5 minutes. Even then, the average speed will be 98 kmph (Mehta, 2024). So, it is not possible to achieve the maximum design speed of 180 kmph for VB trains and the average speed of 140 kmph, given the rail infrastructure IR inherited. However, the Mail/Express trains, Ordinary trains and Freight trains speeds remained at 51 kmph, 35 kmph and 24 kmph, respectively. This once again proves the need to develop an HSR network for faster and more convenient connectivity between cities.

The IR earns more than it spends on freight traffic, and the freight trains get the least priority in the order of track access. The passenger services of Mail/Express and Ordinary trains earn much less than their spending but still get the second and third priority in track access. The Ordinary trains have been losing patronage over the years with the development of the road network, even in the states where they used to get good patronage earlier (Ramakrishnan T S, 22, 2020). It is better to phase out Ordinary trains in stages as the patronage further decreases. If the HSR comes into operation on a route, the premium trains on conventional tracks become redundant, and hence the precedence of trains will be between Mail/Express and freight trains and hence reduce the speed differentials. There is a stagnation and decline of ordinary train patronage, partly due to the development of roads across the length and breadth of India, which provides faster connectivity than ordinary trains and the reduction in the services of ordinary trains by the IR. If people use roads to travel short distances and rail to medium and long distances, at some point in time, ordinary trains will lose their sheen. This would result in only two services of Mail/Express and freight services, and mixed traffic would become more manageable. If we develop dedicated freight corridors, to which most of the freight traffic is shifted, conventional rail lines will have to serve only one service of Mail/Express trains. However, such a scenario could emerge only if the HSR and DFCs are developed across HDN network routes.

In a four-lane road, the faster moving vehicle may steer ahead at the same speed overtaking all the slow-moving vehicles without any interruption as the slow-moving vehicle occupies the other lane. This is not the case with IR traffic in a two-line system. Even if there are third and fourth lines in few sections, the paths need to be allocated carefully to avoid collisions behind. So, even the additional lines may not permit very high speeds as there will be crossings and the movement of slow-moving trains on the adjacent tracks. The Railway Safety Commissioner in 2024 made an order to IR that when the train moves in the mainline, the trains on sidings should not move as it created a couple of accidents (IE, 2024, April 03). This is the precise reason why sidings and crossovers are permitted at stations with high-speed turnouts in HSR in a limited way. Moreover, when the passenger service trains need to stop at stations, they need to switch lines to reach the station platforms and then to leave to mainline from station platforms.

The speed differential between vehicles in road network does not kill the throughput as much it does on railway network. The breaking distance of road vehicles is far less than that of trains as the trains are much longer than the individual vehicles on the road.

2.4 Infeasibility of upgrading rail infrastructure

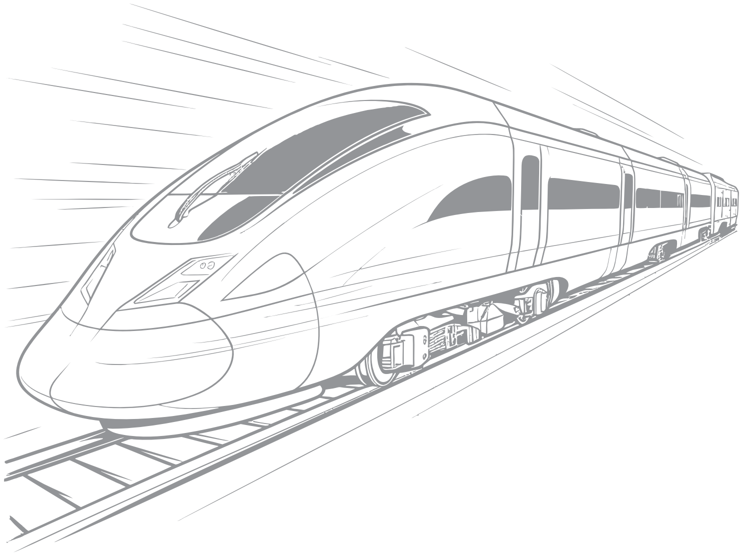
As per the International Union of Railways (UIC, n.d.), the upgradation of the existing conventional railway lines to a maximum speed of up to 200 kmph or 220 kmph is also defined as HSR as much as a new alignment designed for a speed of 250 kmph or more. Hence, there is a scope for IR to increase the speed of existing lines to make them "upgraded HSR." Although IR enhanced the maximum speed of conventional rail operation in a few sections, such as Delhi-Agra and Vapi-Ahmedabad, to 160 kmph, the challenge lies in enhancing the maximum speed to 200 kmph in the conventional lines, both in terms of infrastructure and operations. Even if the maximum speed of some sections is increased to 200 kmph, the mixed traffic conditions of upgraded HSR trains, Freight trains and Mail/Express trains will make the upgraded HSR services untenable to operate for most of the day.

Increasing the maximum speed of IR tracks to 180 kmph-200 kmph in the functioning and heavily loaded conventional rail network as the next level of speed upgrade would be next to impossible, as this will involve realignment of tracks at many places, which means removing all the curvatures. This will involve not only huge costs but also land acquisition, which is very difficult in India now. The existing provisions of IR stipulate fencing at vulnerable locations for speeds above 110 kmph to 130 kmph, and all along the track for speeds above 130 kmph. As of 2024, only 4469 km of route length has fencing (PDL, 2024, February 07, a). This will also require many additional all-weather flyovers (underpasses cannot function effectively during monsoon seasons) at regular distances along the rail route, which will ensure seamless movement of people, cattle, and vehicles across the railway tracks. However, this upgradation can be taken up only if there are HSR corridors running in parallel. The passenger traffic that gets affected during the commissioning of the upgradation of tracks can be shifted to HSR with affordable rates for all passengers during that period only.

2.5 Subdued PRS AC passenger demand

Earlier, in the absence of probability of confirmation data, passengers used to book tickets with waitlisting until the Indian Railway Catering and Tourism Corporation (IRCTC) denied the tickets due to excess waitlisted passengers. According to Tripozo (n.d.), travellers now understand that if the confirmation probability is between 80% and 70%, there are excellent and decent odds of ticket confirmation, while less than 30% have bad chances. This is especially true for travellers in the AC class, which explains why, in comparison to confirmed passengers in the AC rail classes in 2018-19, the waitlisted AC passengers are only around 2% to 3% (RITES, 2020). When AC passengers do not see the probability of confirmation as favourable, they look for air travel at the earliest to save airfare, whereas non-AC passengers have no choice but to wait for waitlisted tickets to confirm or to book tickets under Tatkal or Premium Tatkal. That is why the true demand of AC rail travel is extremely difficult to assess. The double-digit CAGR of domestic air traffic since 2004 and about 15,000 AC buses (which were nearly non-existent prior to 2004) that run between cities, even for modest distances, offering nighttime or dusk-to-dawn travel, serve as the proxy variables to the subdued PRS AC passenger demand. Without HSR, in the absence of confirmed rail tickets, the AC rail classes will likely migrate more and farther to the air for faster but more expensive travel and to the AC buses for more comfortable travel. The IR promised in 2016 that they would provide PRS travel to all those seeking it by 2020 (BS, 2016). In 2023, IR has again promised that they would have a “no-waiting list” before 2030 as IR embarked on the journey of manufacturing trainsets both through its production units and private players (ET, 2023). Adding a few additional coaches when the waitlisted passengers are high has only created a cosmetic effect. However, the scarcity of reserved tickets is not due to the non-availability of trainsets that run at a maximum speed of 160 kmph-200 kmph, but due to the lack of dedicated tracks with no interference from mixed traffic that supports speeds of 250 kmph-350 kmph. This is possible only with HSR.

CHAPTER 03



The Case for HSR Development

The case for HSR development is discussed in this chapter with the following themes.

- The right time
- No clear identification of future routes of HSR
- Substantial gain in capabilities of HSR development
- Shifting preferences to faster and luxury modes
- HSR can reclaim Rail as the first choice of transport
- HSR can reclaim intercity traffic from luxury bus and air
- Substantial gain in capabilities in Semi HSR deployment in India
- Learnings, training and innovation from the first HSR project

3.1 The right time

For HSR to be successful, the start of construction must occur at the right time. As HSR systems are exceedingly expensive to build, operate, and maintain, the nation should have sufficient economic strength and resources to prioritise HSR development above other developmental initiatives. As demonstrated in Table 5, the per capita Gross Domestic Product Purchase Power Parity (GDP PPP) serves as a gauge of these HSR countries' economic strength during the first year of the HSR development.

Table 5 Per capita GDP PPP at the start of HSR construction

Country	HSR System	Year	Per capita GDP PPP (USD)
Japan	Shinkansen	1959	4,700
France	TGV	1976	18,000
Germany	ICE	1973	17,000
Spain	AEV	1987	17,000
Korea	KTX	1992	13,000
Turkey	HT65000	2003	9,900
China	Hexie Hao	2005	4,000
India	Shinkansen	2017	4,730

Source: Takada (2012) & (Trading Economics, (n.d.a)

The first HSRs in Europe were built when per capita GDP PPP exceeded USD 17,000, as Table 5 illustrates. Japan, the HSR's forerunner, started building it in its first year when its per capita GDP PPP was USD 4,700. India started building its first HSR in 2017, and in FY2017-18, the country's per capita GDP PPP was USD 4,730. India's per capita GDP PPP in the commencement year of the construction of the first HSR corridor was higher than that of Japan and China, although it was lower than that of the other nations. The per capita GDP PPP in India was USD 7,400 in FY2023-24 (Trading Economics, n.d.). Based on the assumption that the CAGR of GDP was 6.5% between 2016-20, 4% between 2021-30, 3.7% between 2031-40 and 3.5% between 2041-50, the per capita GDP PPP values for India in the next thirty years would be as shown in Table 6.

Table 6 Per capita GDP PPP of India

Year	GDP PPP (USD)
2020	8,500
2025	10,800
2030	12,800
2035	15,300
2040	18,300
2045	21,900
2050	25,900

Source: (PWC, n.d.)

As per author's calculation based on MoSPI (2024, May 31), India witnessed a CAGR of 3.81% between 2016-20 (41.38% lower than what PWC (n.d.) predicted and 8.3% between 2021-23 (107.5% higher than what PWC (n.d.) predicted. India's GDP growth rate has been consistently high since post-covid. The time has come for India to expand HSR network across the length and breadth of India.

3.2 No clear identification of future routes of HSR

The next set of High Speed Rail corridors has not been identified after 2017. The first HSR corridor was initiated in 2017 with financial support to the tune of 81% of the total cost at an interest rate of 0.1% with a moratorium of 15 years and a repayment period of 50 years. The National Rail Plan (NRP) mentioned that Delhi-Varanasi via Ayodhya, Delhi-Ahmedabad, Varanasi-Patna, and Patna-Kolkata will have to be commissioned by 2031. However, no other corridor was initiated for construction after the first HSR corridor, although umpteen pre-feasibility, feasibility, and DPR reports were generated. If the construction of some of the HSR corridors is not initiated in 2025-2029, it will be too late for India to achieve 8000 km of HSR corridors by 2051 as envisaged in the NRP. After the first HSR route between Ahmedabad and Mumbai is put into service, there will likely be a need for further HSR lines as well; in fact, the overall need for HSR may surpass 12,000 km. Given this, additional HSR corridors building should be started at the earliest.

GoI has not yet made any move in this direction, despite the NRP's proposal to commission Delhi-Varanasi via Ayodhya, Delhi-Ahmedabad, Varanasi-Patna, and Patna-Kolkata by 2031. The execution and commissioning of a HSR corridor can take up to eight years; therefore, the only way they can be commissioned before 2035 is if a few suitable routes are chosen and started by around 2025-2026. Therefore, the purpose of this position paper is to provide the justification for the development of HSR corridors on all dimensions.

3.3 Substantial gain in capabilities of HSR development

Indian engineers, both from Railways and private sector learnt a lot and innovated as a part of constructing the first HSR between Ahmedabad and Mumbai. The technology transfer of Shinkansen from Japan and financial assistance to the tune of 81% at the time of the beginning of the construction and ultimately to 90% have helped Indian Railway engineers and private sector engineers, who are involved in the construction of HSR, gain hands-on experience on the implementation of HSR systems and, in some cases, innovate and customize the system that suits the Indian context.

NHSRCL has adopted many innovative measures as well as training modules along with Japan in the construction of the project on various counts, as briefly listed below:

- High Speed Railways Innovation Centre (HSRIC) trust is undertaking research and development in high-speed rail technology (NHSRCL, n.d.b).

- NHSRCL conducted knowledge sharing workshops for artisans of IR, training programme on HSR track system for Indian engineers and training programme for engineering students in their lab in Surat on Geotechnical Investigation (NHSRCL, n.d.c).
- A lot of customization of construction of HSR system that suits Indian conditions including Shinkansen train sets is being done. For instance, the rolling stock that will be used in Indian HSR will have AC system which can provide coolness up to 50° Celsius compared to 40° Celsius in Japan (Law, 2024).
- The safety features adopted for HSR such as crash avoidance through crash avoidance system, automatic brake application in case of over speeding, early earthquake detection system, continuous rail temperature monitoring, wind monitoring and advanced driver support system are much beyond the safety features adopted for conventional Indian Railways. This would open a new thought process for Indian engineers to feel and develop such systems indigenously.
- 1000 engineers involved in the track laying work have been trained on Track Slab Manufacturing, RC Track Bed construction, Reference Pin survey and data analysis, Slab Track installation, CAM installation, Rail weld finishing, Enclosed Arc welding of rails and Turnout installation by the Japanese experts of Japan Railway Technical Service (JARTS) (NHSRCL, 2021, April, 19).
- The training imparted by Japan to Indian engineers give Indian engineers to adopt a different learning approach. For instance, Indian engineers give priority to acquire broad technical knowledge, which is a deductive approach, whereas Japanese engineers focus on specialized engineering knowledge, which is an inductive approach. Indian engineers tend to place a higher emphasis on management duties and therefore, require a broader range of knowledge to make the right decisions in their wide areas of responsibility in a top-down decision-making business culture. The Japanese engineers follow bottom-up decision-making culture, which can also encourage managerial engineers to adopt a specialized approach. Training of Indian engineers is done with theoretical knowledge first followed by practice, whereas training of Japanese engineers starts with practice and time spent on research and industry-academia collaboration. This type of imparting training helps Indian engineers to adopt to a new way of learning (Harada, 2024).

The railway engineers and the contractors' engineers have gained a great deal of knowledge about how to carry out the HSR project. Their understanding might be limited because certain equipment intended for the HSR system has been arriving in "boxes". Nevertheless, they will have a far greater understanding of the integrated approach and the dynamics of the HSR system by the time the project is finished and put into service. For example, NHSRCL awarded a topographical study, a ridership study, a financial and economic study, and an environmental impact assessment study independently to various consulting firms for the corridors where NHSRCL wants to develop HSR systems in future. Senior executives at NHSRCL then took on the responsibility of writing a coherent and cogent DPR report by compiling these individual reports.

3.4 Shifting preferences to faster and luxury modes

There are at least three factors of faster travel, end-to-end travel, and comfortable travel in the absence of confirmed rail tickets that contribute to the shifting of passengers from rail to other modes of air, luxury bus, and personal car. Air provides the fastest connectivity despite being costlier than other modes. A personal car provides end-to-end connectivity, and a luxury bus provides an immediate alternative to the trains when train tickets are not available. In addition to this inter-mode shifting, even in rail, there is an intra-mode shift towards AC classes from non-AC classes. All these aspects of shifting preferences to faster and luxury modes are explained below.

3.4.1 Preference of rail AC travel

IR has been unable to cope with growing passenger demand across all classes.
However, the demand for AC rail travel has been witnessing much higher growth than non-AC travel as shown in Table 7
The demand for AC and non-AC PRS classes has been outweighing the supply most of the time for many years now. As shown in Table 3, the CAGR of 3AC growth has been very high at 15.48% between 2005-06 and 2018-19, as it provides AC comfort along with reasonable fares. However, the CAGR of 1AC, 2AC, and AC CC is not far behind at 10.75%, 9.21%, and 9.27% respectively, between 2005-06 and 2022-23. IR has been manufacturing and adding more 3AC coaches and other AC coaches to meet the higher growing demand for about 20 years now.

Table 7 Growth of non-suburban rail passenger traffic

Year	Total non-suburban	2nd Class		Sleeper Class		First Class	AC					% share		
		Ordinary Train*	Mail/ Express	Ordinary Train*	Mail/ Express		CC	3AC	2AC	1AC	Total	AC	Sleeper	2nd class
2005-06	509.2	189.11	170.56	1.85	120.09	1.91	4.2	13.42	7.4	0.66	25.68	5.04	23.95	70.63
2006-07	582.87	215.57	190.29	2.94	140.16	1.47	4.94	17.56	9.16	0.79	32.45	5.57	24.55	69.63
2007-08	650.11	224.38	227.16	2.7	154.98	1.59	5.52	22.42	10.45	0.97	39.36	6.05	24.25	69.46
2008-09	713.2	244.08	249.63	2.94	167.08	1.45	5.18	28.78	12.86	1.2	48.01	6.73	23.84	69.22
2009-10	772.55	254.05	270.91	2.9	189.52	1.84	5.44	33.05	13.59	1.26	53.35	6.91	24.91	67.95
2010-11	841.38	278.55	291.7	2.89	206.04	2.02	6.45	38.19	14.1	1.44	60.18	7.15	24.83	67.78
2011-12	902.47	281.46	326.54	3.26	219.06	1.58	7.19	45.31	16.32	1.74	70.56	7.82	24.63	67.37
2012-13	952.45	281.99	347.11	3.52	237.15	1.02	8.67	52.29	18.28	1.89	81.13	8.52	25.27	66.05
2013-14	990.15	288.56	358.29	3.56	250.63	0.82	9.35	58.19	18.75	2.01	88.3	8.92	25.67	65.33
2014-15	995.42	279.51	337.29	3.43	273.97	0.6	10.27	67.01	21.37	1.97	100.62	10.11	27.87	61.96
2015-16	997.79	257.87	349.91	3.6	285.1	0.45	10.75	69.92	22.08	2.11	104.86	10.51	28.93	60.91
2016-17	1004.42	260.02	341.18	3.84	289.02	0.43	11.55	73.72	22.4	2.26	109.93	10.94	29.16	59.86
2017-18	1028.24	268.52	347.68	3.58	294.2	0.43	11.63	76.92	22.95	2.32	113.82	11.07	28.96	59.93
2018-19**	1010.5	219.35	369.84	3.52	291.14	0.4	13.29	87.21	23.25	2.49	126.24	12.49	29.16	58.31
2019-20	913.6	128.58	383.86	1.85	267.63	0.35	10.66	95.6	22.77	2.31	131.34	14.38	29.5	56.09
2022-23	844.57	37.29	323.63	0.09	280.26	0.12	12.29	155.77	31.47	3.66	203.18	24.06	33.19	42.73
CAGR between 2005-06 and 2018-19	5.41	1.15	6.13	5.07	7.05	-11.33	9.27	15.48	9.21	10.75	13.03			

*Ordinary trains refer to multi station stopping passenger services which operate at an average speed of 35 kmph

**The data from 2019-20 & 2020-21 are not considered here as by the beginning 2020, the train travel reduced due to Covid and still has to come back to previous Covid level Source: Author's calculation based on IR (2006), IR (2008), IR (2008), IR (2010), IR (2012), IR (2014), IR (2016), IR (2018), IR (2020), IR (2022) and IR (2024)

Table 8 Supply of AC seats versus no-AC seats in IR

Year	No of berths/seats (All trains)				Share (%) (All trains)		
	AC (PRS)	Sleeper (PRS)	2nd class (UTS)	Total	AC	Sleeper	2nd class
2010-11	3,51,800	10,55,400	28,44,300	42,51,500	8.27	24.82	66.9
2021-22	9,28,610	17,24,561	34,39,080	60,92,251	15.24	28.31	56.45
CAGR % (2010-11 to 2021-22)	9.22	4.57	1.74	3.32			

Source: Author's calculation based on Annual Account Statements of IR 2010-11 and 2021-22

Taking advantage of the preference for rail AC travel. IR increased the rail AC seats much more than rail non-AC seats as shown in Table 8.

IR has been manufacturing and adding more AC coaches, especially 3AC, to meet the higher growing demand for about 20 years now. Despite this, IR has not been able to meet the growing AC class passenger demand, and this is evident from the substantial number of waitlisted passengers and the exponential growth of air and luxury bus travellers.

3.4.2 Air travel exceeded rail AC travel

A comparative analysis of air travel and non-suburban rail AC travel is given in Table 9 between 2013-14 and 2019-20, the last year before COVID.

Table 9 Domestic Air travel versus Rail AC class travel

(in Billion PKM)

	Air	Rail AC classes				Total Rail AC	Ratio of Air traffic to Rail AC traffic (%)
Year		**AC CC**	**3 AC**	**2AC**	**1 AC**		
2013-14	59	9.35	58.19	18.75	2.01	88.30	66.98
2014-15	67	10.27	67.01	21.37	1.97	100.62	66.61
2015-16	81	10.75	69.92	22.08	2.11	104.86	77.21
2016-17	99	11.55	73.72	22.40	2.26	109.93	89.73
2017-18	117	11.63	76.92	22.95	2.32	113.82	102.83
2018-19	135	13.29	87.21	23.25	2.49	126.24	106.84
2019-20	137	10.66	95.60	22.77	2.31	131.34	104.08
CAGR % (2013-14 to 2018-19)	7.9	8.43	4.40	4.18	7.41	6.84	7.62

Source: Author's calculation based on IR (2020) and DGCA (n.d.)

The CAGR indicates that air growth is bound to happen twice at the rate of AC rail in the business-as-usual scenario. As per this, air traffic would double in five years, whereas AC rail traffic would increase only by 44% in five years from 2019-20. The air traffic exceeded AC rail traffic as early as 2017-18. This data also emphasises the need to provide faster rail services, and that is possible only when India develops HSR across India at the earliest.

3.4.3 Luxury bus travel exceeded rail AC travel

In India, the pickup of luxury buses for intercity travel since 2004 has been phenomenal. The Volvo buses were introduced in India in 2001, and by 2011 more than 5000 buses had been plying by the omni bus agencies on intercity trips (Shukla, 2012). Gujarat State Road Transport Corporation (GSRTC) introduced 41 Volvo bus schedules per day between Ahmedabad and Vadodara all along the Expressway when it was opened in 2013-14 (TOI, 2011). Volvo and Scania buses in 2018 on the Agra-Lucknow Expressway, where only private tourist buses ran till that point in time (Lavania, 2018).

Buses ply between Bengaluru and Jodhpur (a distance of 1950 and a travel time of about 32 hours) with a fare that is almost equal to 2AC train travel. The travel time between Tirunelveli and Chennai by rail reduced from 13 hours to about 11 hours over the last few decades, whereas the bus travel time reduced from 13 hours to 8 hours over the same period. The bus operators also introduced sleeper coaches, or combinations of seating and sleeper coaches, across Premium and Value Plus buses. Some of them even introduced chemical toilets in the buses (ET, 2012, July 18). The throughput of the road network has also improved as the four-laned/six-laned road network provides scope for slow-moving trucks and fast-moving cars and buses.

Luxury bus operation across various cities in India is a completely disaggregated market. However, the Market Assessment for Intercity Electric Buses in India carried out by Transit Intelligence LLP in June 2024 tried to estimate intercity bus transport (both AC and non-AC buses) with the following aspects:

- India's bus fleet is about 23 lakhs in 2023, which may increase to 32 lakhs in 2031. The ratio of public to private buses is 7% to 93%.
- About 70% of all intercity trips across seaters, sleepers, semi-sleepers, and their combinations have been operated using air-conditioned (AC) buses.
- There are 32,654 services originating every day from the top 17 demand centres in India. The top centres are Ahmedabad, Bengaluru, Bhopal, Bhubaneswar, Chandigarh, Chennai, and Delhi. Among the 32,654 services, 25,000 services were arriving at 167 cities and towns, and the remaining were to other smaller towns. As the services are to be operated in both directions, there are about 65,000 services operated from these top 17 centres to various cities and towns in both directions.

Based on the above aspects, the collated data on private AC bus services is listed in Table 10 (non-AC services constitute only 29.5% of the traffic)

Table 10 Estimate of intercity AC Bus traffic in India in 2024

Description	Trips (%)	Daily services	Avg. route length (km)	Total passengers	Total BPKM per day (one direction)	Total BPKM per year (Both directions)	Fare (INR)
AC Sleeper	44	14,368	432	4,02,304	0.1738	121.66	5.8
AC Seater Sleeper	15	4,898	440	1,37,144	0.0603	42.21	4.7
AC Semi Sleeper	6	1,959	355	54,852	0.0195	13.65	4.1
AC Seater	5	1,633	210	45,724	0.0096	6.72	4.5
AC Seater Electric	0.5	163	215	4,564	0.001	0.7	1.7
Total AC Services*	70.5	23,021		6,44,588		184.94	5.3

Note: Assumptions for PKM calculations:

- The occupancy rate is taken to be 80% based on the ratio of 65% to 35% of peak season to non-peak season.
- The number of days that AC buses operated are taken as 350
- The number of daily services given in one direction, is doubled to estimate the daily services in both directions.

Source: *Author's calculations from Transit Intelligence LLP (2024, June)*

The additional information pertaining to Table 10 are as follows:

- The Traffic estimate is conservative since AC buses operating beyond the 17 top demand centers and those operated by various State Road Transport Corporations (SRTCs) have not been included in the table.
- The average route length is about 200 km to 450 km although some buses operate beyond 1000 km.
- Presently, AC electric buses constitute only 0.5% of the total intercity buses operated by the omni bus operators. These buses are essentially run only from the cities of Bhopal, Indore, Chandigarh and Hyderabad. However, this would increase in future considering the factors of Total Cost of Ownership (TCO) and fuel cost
    - The TCO for 12-meter Diesel bus for operating 500 km per day for 12 years is INR 56.4 per km. The TCO for comparable AC E-bus with a battery capacity of 365 kwh to 395 kwh ranges between INR 47.6 and INR 49.6.
    - The fuel cost alone constituting about 63% of the fares of ICE AC buses.
- INR 5.3 is the weighted average fare paid by AC bus travellers per km now. As the influx of E-buses increases, the fares of AC intercity buses may decrease despite the increase in upfront investment, as the fuel costs are much less.

The comparison of passenger travel by Rail AC classes with AC buses is shown in Table 11.

Table 11 Intercity AC bus vs. Rail AC traffic in BPKM

Year	AC Buses	Rail AC classes				
		AC CC	3 AC	2AC	1 AC	Total
2023-24	184.94	9.64	64.92	19.86	2.15	96.87*

* AC rail travel is extrapolated for 2023-24 from 2022-23

Source: Collated luxury bus travel data from Table 9 and AC rail travel is extrapolated for 2023-24 from 2022-23

The key inference of Table 11 is that AC bus travel in 2023-24 is at least 1.91 times that of AC rail travel. Any backward extrapolation would indicate that AC bus travel would have exceeded AC rail travel even a few years back. It has been observed that whenever a new train is introduced in a corridor, the bus market dips for three to six months and regains its traffic only after that. This indicates that the growth of the bus market between key O-D pairs primarily originated due to a lack of supply of train services.

3.4.4 Cost of HSR travel versus AC rail, AC Bus and economy Air travel

The cost of various AC rail classes' travel versus AC bus and economy air travel, along with the expected fare for the standard class of HSR for a distance of about 500 km (Ahmedabad-Mumbai) in 2024, is given in Table 12.

Table 12 Fares of HSR vs. other modes for 500 km (2024)

Description	HSR standard class[2]	Rail AC classes[1]					AC Bus[3]	Air Economy[4]
		CC	3 AC	2AC	EC	1 AC		
Fare (INR)	2910	665	815	1,150	1,930	1,940	2500	2500
Approx. Onboard travel time (minutes)	160	395					600	60
Approx. End-to-end travel time (minutes)	280[5]	515[5]					720[5]	240[6]

[1] Fares are for Ahmedabad-Mumbai

[2] HSR standard class fare is 1.5 times that of 1AC. There will be Business class and First class with one coach each in a 10-coach trainset.

[3] The average fare for AC bus as explained in section 2.4.2 is about Rs 5 in 2024. They are not telescopic in nature in general.

[4] The average fare of Air Economy is about INR 5 (as cross verified from various sources). However, the standard deviation of the fare will be high, where early booked tickets for 500 km travel may be available for INR 1750 only but the eleventh hour booked tickets may cost more than INR 4000. The air fares of budget airlines fix the fare on ten slots, the first slot is the lowest and the tenth slot is the highest as the booking increases and the day of travel nears.

[5] For rail AC , AC bus and HSR, the access, waiting and egress time was taken as 2 hours.

[6] For air, the access, waiting and egress time was taken as 3 hours.

Source: Author's calculation based on ToI (2024, May 27), JICA (2015, June) & Trainman (n.d.)

The key inferences from Table 12 are as follows:

- Comparing HSR with air in terms of the cost of onboard travel and end-to-end travel time, they are almost the same, which means there will be a 50% modal shift towards HSR from air.
- Comparing HSR with AC bus in terms of the cost of onboard travel, both are almost the same. In terms of end-to-end travel time, the bus travel is about 2.5 times that of HSR travel. As a result, there will be a huge shift from AC bus travel to HSR. The scope for reducing the fare of AC buses is limited for both ICE buses and electric buses, as the fuel cost is about 60% of the total cost in ICE vehicles, and the upfront investment for batteries for electric buses cannot permit the AC bus agencies to reduce the fare.
- Comparing HSR with 1AC and EC of AC rail classes in terms of the cost of onboard travel, both are almost the same. However, the rail travel will take about 4 hours more than the HSR travel, and the shift towards HSR from these classes will be very high. In fact, IR may have to replace 1AC and EC coaches with other coaches to sustain the occupancy once HSR is commissioned. The cost of travel by CC and 3AC is less than half the HSR cost. Thereby, the shift towards HSR from these classes will be moderate.

3.5 HSR can reclaim Rail as the first choice of transport

3.5.1 Huge capacity creation of HSR for passenger traffic

The capacity for passenger traffic created by 500 km of HSR can be estimated based on the following supply-side assumptions: However, the schedule and utilization will be based on the traffic demand.

- As per Emery (2011, May 22), for High-Speed Trains at 300 km/h without merging or splitting routes and no intermediate stops, the practical headway is 3 min with ETCS_L2-FS and 2½ min with ETCS_L2-TFS. So, it is assumed here that HSR can operate a maximum of 20 services in an hour in one direction.
- The maximum speed is 320 kmph and the average speed is based on whether the HSR service is a limited stop service (LSS) or it will stop at all the stations. NHSRCL estimated that the travel time of the 508 km stretch from Ahmedabad to Mumbai with LSS (with stoppages at Vadodara and Surat only) is 2 hours and 4 minutes, and with stoppages at all the 10 stations in between, the travel time would be 2 hours and 35 minutes. Here it is assumed liberally that LSS service and all-stop service will require a travel time of 2 hours 15 minutes and 2 hours 45 minutes, respectively. It is also assumed that all the services are non-LSS services.
- It is assumed that the HSR will operate between 6 AM and 11 PM, and the rest of the time will be used for daily maintenance work. However, the last service in either direction should depart at 8:15 PM to reach the destination at 11 PM. So, between 6 AM and 08:15 PM, a maximum of 283 services can be operated in one direction in a day.
- The number of days per year is taken as 365.
- As per NHSRCL data, the 10-coach E5 trainset and the 16-coach E5 trainset supplied by Japan will have the seating capacity of 690 and 1104, respectively. It is assumed here that the train sets that will be deployed for HSR services will be 16-coach trainsets so that the HSR paths are optimally utilized. It is assumed here that each train set will provide 1100 seats for the passengers.
- It is assumed that the occupancy is 80%. The occupancy is taken as the ratio of seat-km utilized to the available seat-km and not in terms of passengers.

To estimate the capacity creation of HSR for a distance of 500 km for various levels of capacity utilisation in relation to IR conventional rail of distance of 500 km, the following assumptions are made.

- The number of seats in a 10-coach E5 trainset in the configuration of one Grand class coach, one Business class coach, and eight Standard class coaches supplied by Japan will have 690 seats altogether. The average occupancy of the train was taken as 80%. In the same proportion, 16 coach E5 trainsets will have 1104 seats. Here it is assumed that each HSR trainset will have 1100 seats. If the HSR trainset is 24 coaches, the capacity would increase by 50%.

- 100% Capacity Utilization of the HSR corridor means the following:
    - The HSR services operate between 6 AM and 11:30 PM in both directions. The HSR services will depart with a headway of 3 minutes between 6 AM and 8:45 PM in both directions.
    - The overall occupancy rate of HSR services is 80%.

The percentage of capacity utilisation along with yearly traffic and throughput of a 500 km stretch HSR corridor in comparison with conventional rail, is shown in Table 13.

Table 13 Ratio of capacity by HSR and conventional rail

HSR				Conventional IR tracks (2017-18)*			Ratio of Capacity (HSR to IR tracks)
Capacity Utilisation (%)*	Services per day (both directions)	Yearly BPKM	Throughput (MPKM per Track km)	Running Track km	Yearly BPKM	Throughput (MPKM per Track km)	
100	566	103.3	103.3	94,270	1,178	19.22	5.37
90	509	92.89	92.89	94,270	1,178	19.22	5.01
80	453	82.67	82.67	94,270	1,178	19.22	4.3
70	396	72.27	72.27	94,270	1,178	19.22	3.76
60	340	62.05	62.05	94,270	1,178	19.22	3.23
50	283	51.65	51.65	94,270	1,178	19.22	2.69
40	226	41.25	41.25	94,270	1,178	19.22	2.15
30	170	31.03	31.03	94,270	1,178	19.22	1.61
20	113	20.62	20.62	94,270	1,178	19.22	1.07
10	57	10.4	10.4	94,270	1,178	19.22	0.54
5	28	5.11	5.11	94,270	1,178	19.22	0.27

*2017-18 witnessed maximum yearly BPKM and hence it was taken for analysis

The values above were derived as follows:

Calculations are for a route length of 500 km (track length of 1000 km)

For HSR

Max.services per hour=20 (with a headway of 3 minutes)

Services per day (both directions) = Capacity Utilisation %×Max.services per hour×14.15

End to end passengers (both directions)= Passenger seats per train×Occupancy rate×Trains per day×2

Yearly BPKM=End to end passengers (both directions)×500×365

Throughput (MPKM per Track km)= Yearly BPKM per 1000 Track km

where 1000 is track km for Route km of 500

For conventional rail

IR uses 65% of the track resources for passenger transport against 35% for freight services. As per 2022-23 IR data, the Train km of passenger services and freight services were 750.57 million and 553.07 respectively, resulting in the track usage of 58% and 42% respectively. Apart from Train km, passenger trains occupy the tracks while boarding and deboarding passengers and hence the share of track usage by passenger services was taken as 65% against 35% for freight trains.

The key inferences from Table 13 are as follows.

- At 100% HSR capacity utilization, HSR creates 5.37 times capacity that of conventional rail.
- For a very well utilized HSR network like the Tokaido Shinkansen, the number of services in a day is 336 (Central Japan Railway Company, n.d.). This means one of the most successful HSR corridors in the world achieved a capacity utilization of 50%-60%. However, all HSR corridors need not have to achieve similar feats. Even in Japan, Sanyo, Tohoku, Joetsu, Hokuriku, and Kyushu provide daily services of 164, 181, 90, 67, and 34, respectively (IHRA, n.d.), corresponding to the capacity utilization of about 20% -30%, 30%-40%, 10% -20%, 10% -20% and 5% -10%, respectively.
- When the capacity utilization of HSR decreases, the ratio of capacity of HSR to conventional rail decreases accordingly. At 50% capacity utilization of HSR, the HSR capacity is 2.69 times that of conventional rail. At about 20% of capacity utilization of HSR, the HSR capacity is about the same as that of IR conventional tracks.
- With 5% capacity utilization, HSR may transport 28,000 end-to-end passengers per day and 1,02,20,000 passengers per year. Literature on HSR suggests that an HSR corridor will become financially viable if the yearly end-to-end passengers are above 90 lakhs. So, even with 5% capacity utilization, HSR can become financially viable.

3.5.2 Expected capacity utilization of Ahmedabad-Mumbai HSR

In order to understand the larger implications of how much capacity utilisation and throughput one can expect from the large number of HSR corridors India may have to construct, it is better to estimate the capacity utilisation and throughput of the Ahmedabad-Mumbai corridor considering two dimensions.

1. As per the NHSRCL plan for the first 30 years of operation
2. As per ridership estimation by JICA Detailed Project Report and by the author's dissertation

The capacity utilisation and throughput of the first HSR corridor of Ahmedabad-Mumbai, as per the NHSRCL plan of operations, is shown in Table 14.

Table 14 Capacity analysis of first HSR corridor (NHSRCL operations plan)

Description	1st Year of Operations*	10th Year of Operations	20th Year of Operations	30th Year of Operations	Parameters for Max capacity
Train configuration	10	10*16	16	16	16
Number of rakes	24	24+11	44	71	
Number of trains (per day/ one-direction)	35	51	64	105	290
Train capacity	690	690/1250	1250	1250	1250
Passenger seats (day/one direction)	17,900	31,700	56,800	92,900	362500
Number of trains (per day/one direction) Peak	3	4	6	8	20
Non Peak Hour	2	3	3	6	20
No of services					
6 AM- 9 AM	9	12	18	27	60
9 AM - 5 PM	15	24	24	50	160
5 PM-8:30 PM	11	15	22	29	70
Total (one direction)	35	51	64	105	290
MPKM available per day both directions	18.19	32.21	57.71	94.39	368.3
BPKM available per year both directions (365 days)	6.64	11.76	21.06	34.45	134.43
Capacity utilisation (%)	4.94	8.75	15.67	25.63	100
Throughput MTKM/Route KM	13.07	23.15	41.46	67.81	264.63

Source: Author's calculation based on NHSRCL (n.d.a)

**The NHSRCL operation plan assumed that the first year of operations will be 2023 and thereby 10th year, 20th year and 30th year by 2033, 2043 and 2053 respectively. However, the project got delayed and hence it is expected to be commissioned by 2030 and thereby the first year, 10th year, 20th year and 30th year of operations will be 2030, 2040, 2050 and 2060. The entire calculations based on the initial commissioning year will change towards higher passenger seats, number of trains per day, BPKM available per year both directions, and better capacity utilization.*

The key inferences from Table 14 are as follows.

- The NHSRCL operation plan stated that in peak hours, there will be three 690-seater, 10-coach trainsets per hour, and in non-peak hours, there will be two trains per hour in each direction in the first year of service. The peak hours are three hours in the morning and three and half hours in the evening. At the end of the 1st year, 10th year, 20th year, and the 30th year of operation, the capacity utilization would be 4.94%, 8.75%, 15.67% and 25.63%, respectively.
- As per the NHSRCL operation plan, in the first year of operation, the capacity utilization of Ahmedabad-Mumbai HSR is expected to be 4.94%, and however, at the end of 30 years, the capacity utilization is expected to increase to 25.63%, which is substantial by any international standard of utilization of the HSR corridor.

The NHSRCL operation plan based on the expected ridership seems to be very conservative. The capacity utilization of the Ahmedabad-Mumbai HSR corridor, as per JICA DPR, is almost on par with the NHSRCL operation plan, as NHSRCL so far planned their operations based on the JICA ridership estimates. The capacity utilization of the Ahmedabad-Mumbai HSR corridor, as per the author's PhD dissertation, is at least seven times more than that of JICA DPR. However, if NHSRCL carries out a fresh ridership study a few years before the expected commissioning of the Ahmedabad-Mumbai corridor, it would help them to revise their operations plans and rolling stock procurement accordingly. The capacity utilization and throughput of first HSR corridor of Ahmedabad-Mumbai as per DPR of JICA and author's PhD dissertation operations is shown in Table 15.

Table 15 Capacity analysis of first HSR corridor (JICA and Author)

Description	Route length (km)	BPKM	Throughput (MPKM per Track km)	Max. capacity (BPKM)	Capacity utilisation (%)
As per DPR of JICA					
2023 (first year)	508	4.2	8.27	138	3.04
2030	508	6.39	12.58	138	4.63
2035	508	8.37	16.48	138	6.07
2040	508	10.97	21.59	138	7.95
2045	508	14.37	28.29	138	10.41
2050	508	18.83	37.07	138	13.64
As per author's PhD dissertation					
2025	508	24.38	47.99	138	17.67
2030	508	49.28	97.01	138	35.71
2035	508	86.36	170.00	138	62.58

Source: JICA (2015, June)

Unlike the conservative estimate of capacity utilization by JICA DPR for the Ahmedabad-Mumbai HSR corridor, which estimated that the capacity utilization would be only 13.64% by 2050, the author's PhD dissertation estimated that the capacity utilization of the first HSR corridor of India will be 35.71% in 2030, the expected first year of operation, and will rise to 62.58% in the 5th year of operation, much more than the Tokaido Shinkansen. If the ridership estimation of the author's PhD dissertation comes true, the additional revenue and profit from the first HSR corridor may be used to construct other HSR corridors as well as to enhance the existing conventional IR network.

It is imperative to compare the expected utilisation of the first HSR in India with the countries that have developed HSR on a large scale to see whether the first Indian HSR capacity utilization will be on par with the HSR of world countries. The capacity utilisation and throughput for the top HSR countries for 2019 (pre-covid) are shown in Table 16.

Table 16 Capacity analysis for some HSR countries in 2019

Country	Ridership (Million)	Yearly BPKM	Lead (km)	HSR distance (km)	Throughput (MTKM per Route KM)	Max capacity (BPKM)	Capacity Utilisation (%)
China	2357.7	774.7	329	26621	29.00	7221	10.73
Japan	354.6	99.3	280	3042	33.00	825	12.03
France	125.9	60	477	2794	21.00	758	7.92
Germany	99.2	33.2	335	3572	9.00	969	3.43
Spain*	41.2	16.1	391	4502	4.00	1221	1.32
India							
Ahmedabad-Mumbai HSR in 2050 as per JICA DPR	37.07	18.83	300	508	37.07	138	13.64
Ahmedabad-Mumbai HSR in 2035 as per author's PhD dissertation		86.36		508	170	138	62.58

*Spain picked up HSR traffic fast enough to surpass its post-Covid value as they introduced competition between various private players to operate HSR trains

Source: Author's calculation based on Statista (n.d.a)

On expected lines, Japan had the highest capacity utilization, followed by China, France, Germany and Spain in 2019, a year before covid. But in 2021, during and after covid, the HSR ridership and hence the capacity utilization reduced for almost every country except Germany. Many of these countries on their way to exceed their ridership before covid and Spain increased its ridership beyond pre-covid level faster than other countries by about 5%.

Table 16 clearly indicates that the ridership, throughput and capacity utilization of the first HSR between Ahmedabad and Mumbai in India, as per JICA DPR, are higher than the ridership, throughput and capacity utilisation of combined HSR corridors of various countries. There is a caveat. The performance of HSR of countries mentioned in Table 15 are of HSR corridors with huge ridership, moderate ridership, and low ridership. So, it is better to compare the first HSR corridor of India with the individual HSR corridors of Japan, which is the first country to introduce HSR and developed an extensive HSR network in its country. The capacity utilisation and throughput for the top Shinkansen corridors for 2019 (pre-covid) are shown in Table 17.

Table 17 Capacity analysis of Shinkansen corridors before Covid

Shinkansen corridor	HSR route length (km)	Yearly BPKM	Throughput (MPKM per Route length)	Max. capacity (BPKM)	Capacity utilization (%)
Tokaido Shinkansen	515	52.94	103	140	37.81
Sanyo Shinkansen	554	18.72	34	150	12.48

Tohoku Shinkansen	675	14.41	21	183	7.87
Joetsu Shinkansen	334	4.58	14	91	5.03
Hokuriku Shinkansen	471	3.61	8	128	2.82
Kyushu Shinkansen	257	1.95	8	70	2.79
Hokkaido Shinkansen	149	0.22	1	40	0.55
Sum of 7 corridors	2955	96.43	33	802	12.02
First HSR of India (2050) JICA DPR	508	18.83	37	138	13.64
As per author's PhD dissertation 2035	508	86.36	170	138	62.58

Source: Author's calculation based on Statista (n.d.b)

The key inferences from Table 17 are as follows:

- The highest capacity utilization is in the Tokaido Shinkansen. Even here, the capacity utilization is 37.81%. In comparison with the Tokaido Shinkansen, the expected utilization of the Ahmedabad-Mumbai HSR corridor is not far behind.
- The capacity utilization of the top seven Shinkansen corridors gives an indication that all HSR corridors may not have similar patronage. However, it is in the interest of the nation to develop many HSR corridors. It is also to be noted that the HSR corridors that have higher capacity utilization may compensate the HSR corridors with lower capacity utilization. The HSR development is to be seen holistically rather than looking at individual corridors.

3.6 HSR can reclaim intercity traffic from luxury bus and air

If HSR is not built across India now on a large scale, luxury bus travel will grow unabatedly, leading to more congestion in the NH and Expressways and force the government to add more lanes at every few years on the existing highways or forced to construct highways on new alignment. The double-digit growth of air traffic will also go unabatedly leading India to create either additional terminals or new airport for each city for every decade (Kaur, 2023, March 22). Delhi and Mumbai have been constructing an additional airport apart from the existing airport and Bengaluru is planning to construct the second airport. Chennai is planning to develop a new airport with higher capacity.

Despite up to 40% surge in flight ticket prices, India's domestic air fares are the lowest compared to global fares (ToI, 2024, May 27). The airlines cannot reduce the prices further but only can increase the prices substantially. The disappearance of air service players such as King Fisher and Jet despite enjoying higher share in the air traffic is an indication that the low fares that the budget carriers at present cannot be sustained for a long time and hence, they will be forced to increase the fares substantially. With hugely reduced travel time (such as 6 hours to 2 hours or 14 hours to 4 hours) and high-level comfort with amenities at a cost much less than late booking air and AC bus fares, modal shift may happen towards HSR. In this backdrop, there is a big opportunity for HSR to operate at reasonable fares and can make use of "Economies of Scale".

The rail passenger traffic and its share as per the "India Transport Report (ITR) - Moving India to 2032" generated by the National Transport Development Policy Committee headed by Dr. Rakesh Mohan and the actual passenger traffic that was achieved by IR for FY2011-12 was 1047 BPKM, which accounted for 10% of the total passenger traffic. Only rail and road traffic were considered in this calculation. However, in 2016-17, ITR estimated that rail passenger traffic would be 1509 BPKM. The Energy and Resources Institute (TERI) report released in December 2023 estimated that between 2008-09 and 2017-18, long-distance AC passengers grew at a CAGR of 9%, whereas long-distance non-AC passengers grew at a CAGR of 1.44%. The tendency to look for high-comfort travel despite high cost has been the reason for the higher growth of AC passengers over the last two decades. When the affordability and willingness to pay increase substantially, even among a certain significant percentage of the population, it indicates that HSR travel would get better patronage, shifting people from luxury buses, cars, luxury rail, and air.

3.7 Substantial gain in capabilities in Semi HSR deployment in India

The International Union of Railways (UIC) defines semi high speed train as the one which operates at a maximum speed of 160 kmph to 200 kmph and average speed of about 110 kmph. As none of the premium trains before the introduction of Namo Bharat of Regional Rapid Transit System (RRTS) or Vande Bharat trains achieved this speed, the introduction of Namo Bharat and Vande Bharat trains in the last five years increased the capabilities of rail transport in India.

3.7.1 Regional Rapid Transit System of National Capital Region

The Regional Rapid Transit System (RRTS) of National Capital Region (NCR) started to function for 17 km between Sahibabad and Duhai Depot from Oct 20, 2023, and a contiguous stretch of 17 km between Duhai to Modi Nagar North in the Delhi- Meerut RRTS corridor. The maximum speed of the RRTS trains will be 160 kmph (design speed of 180 kmph) and the average speed will be 80 kmph, thereby covering the distance of Delhi-Meerut in one hour. RRTS system is being constructed on standard gauge and functions with trainsets and achieve the maximum speed of 160 kmph, which none of the conventional railway trains have achieved. This is possible because of dedicated corridor with viaduct or underground tunnels and uses state of the art technologies as listed below.

- Indigenously manufactured pre-cast ballast less tracks that support design (NCRTC, n.d.a)
- SPEED, which is a project management and monitoring tool for capturing reporting activities of pre-construction and construction phases of the Project in real time and a cloud-based sophisticated, robust, reliable, and user-friendly platform, developed in-house (NCRTC, n.d.b)
- Building Information Modelling (BIM), which is an intelligent 3D model-based process that provides architecture, engineering, and construction professionals the insights & tools to more effectively plan, design, construct, and manage buildings & infrastructure. BIM facilitates in such a way that components are modelled in 3D with the help of various BIM software and a single database (BIM model) combines information from all disciplines – Architecture, Structure, Mechanical, Electrical, Plumbing and Fire Safety, etc. (NCRTC, n.d.c).
- European Train Control System (ETCS) Level 2 which includes Automatic Train Protection (ATP), Automatic Train Operation (ATO) and Automatic Train Supervision (ATS) using radio communication between track side and train (NCRTC, n.d.d).
- Continuously Operating Reference Station (CORS), which provides real time precise coordinates for the measured locations and can ensure 5-10 mm accuracy in location points for accurate civil structure alignment (NCRTC, n.d.e)
- RRTS trains have push buttons for selective opening of doors, which eliminates the opening of all doors at every station, thus leading to energy saving (NCRTC, n.d.f).

3.7.2 Deployment of Vande Bharat Trains

The indigenous development of VB trainset set a record that India developed a trainset for long journey, which can run at a maximum speed of 180 kmph and thereby improved the capability of Indian Railways substantially. The special features of a VB trainset are listed below (PIB, 2023, August 02).

- Fitted with KAVACH.
- Faster acceleration
- Fully Sealed Gangway for Free Passenger Movement
- Automatic Plug Doors
- Reclining Ergonomic Seats and Comfortable Seating with revolving seats in executive class
- Better Ride Comfort.
- Mobile charging sockets for every seat.
- Mini Pantry with provision of Hot Case, Bottle Cooler, Deep freezer & Hot Water Boiler
- Direct and Diffused Lighting.

- Special lavatory for Divyangjan passengers.
- Emergency openable Windows and fire extinguisher in each coach
- CCTVs in all Coaches
- Emergency Alarm Push buttons and Talk Back Units on all Coaches.
- Better fire safety – Aerosol based fire detection and suppression system in electrical cabinets and lavatories
- Driver-Guard communication with voice recording facility & Crash hardened memory
- Coach Condition Monitoring System (CCMS) display with remote monitoring
- Disaster lights – 4 numbers in each coach in case of Emergency
- 4 platform side cameras including rear view cameras outside the coach.
- 30% reduction in energy consumption compared to loco hauled trains

3.8 Learnings, training and innovation from the first HSR project

When building the first HSR between Ahmedabad and Mumbai, Indian engineers from the private sector and the railways learnt a lot and came up with innovative ideas. Indian Railway engineers and private sector engineers involved in HSR construction have been obtaining practical experience in implementing HSR systems and, in certain cases, innovate and adapt the system to the Indian context.

As briefly mentioned below, NHSRCL has used numerous innovative approaches and training modules during the project's construction on a number of counts:

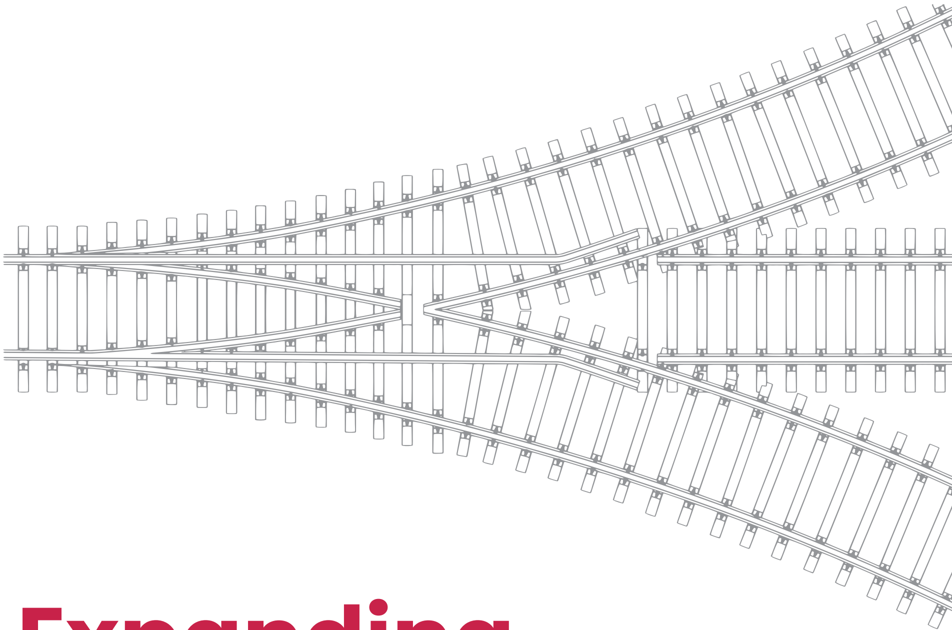
- High-speed rail technology research and development is being carried out by the HSRIC Trust (NHSRCL, n.d.b).
- NHSRCL held workshops for IR artisans to exchange knowledge, trained Indian engineers on the HSR track system, and trained engineering students on geotechnical research in their Surat lab (NHSRCL, n.d.c).
- Shinkansen trainsets and other aspects of the HSR system's construction are being heavily customized to fit Indian circumstances. The Indian HSR's rolling stock, for example, will include air conditioning that can cool it to 50°C instead of 40°C. (NHSRCL, 2021, June)
- The advanced driver support system, automatic braking in the event of an over speeding incident, early earthquake detection system, continuous rail temperature monitoring, wind monitoring, and crash avoidance through a crash avoidance system are just a few of the safety features that HSR has implemented that go far

beyond those of traditional Indian Railways. This would give Indian engineers a fresh perspective on how to feel and create such systems domestically (NHSRCL, n.d.d).

- The Japanese experts of Japan Railway Technical Service (JARTS) trained 1000 engineers involved in the track-laying work in the following areas: Track Slab Manufacturing, RC Track Bed construction, Reference Pin Survey and Data Analysis, Slab Track installation, CAM installation, Rail weld finishing, Enclosed Arc welding of rails, and Turnout installation (NHSRCL, 2021, April, 19).
- The training imparted by Japan to Indian engineers gives Indian engineers the ability to adopt a different learning approach. For instance, Indian engineers give priority to acquiring broad technical knowledge, which is a deductive approach, whereas Japanese engineers focus on specialized engineering knowledge, which is an inductive approach. Indian engineers tend to place a higher emphasis on management duties and therefore require a broader range of knowledge to make the right decisions in their wide areas of responsibility in a top-down decision-making business culture. The Japanese engineers follow a bottom-up decision-making culture that can also encourage managerial engineers to adopt a specialized approach. Training of Indian engineers is done with theoretical knowledge first, followed by practice, whereas training of Japanese engineers starts with practice and time spent on research and industry-academia collaboration. This type of imparting training helps Indian engineers to adapt to a new way of learning (Harada, 2024).

The railway engineers and the contractors' engineers have gained a great deal of knowledge about how to carry out the HSR project. Their understanding might be limited because certain equipment intended for the HSR system has been arriving in "boxes." Nevertheless, they will have a far greater understanding of the integrated approach and the dynamics of the HSR system by the time the project is finished and put into service. For example, NHSRCL awarded a topographical study, a ridership study, a financial and economic study, and an environmental impact assessment study independently to various consulting firms for the corridors where NHSRCL wants to develop HSR. Senior executives at NHSRCL then took on the responsibility of writing a coherent and cogent DPR report by compiling these individual reports.

CHAPTER 04



Benefits of Expanding The HSR Network In India

4.1 Reduction in IR subsidy burden on rail AC travel

IR has not been able to recover its cost on passenger services except premium trains. In FY2022-23, IR earned 54 paisa for every rupee it spent on passenger services (PDL, 2024, July 24, c). In FY2023-24, IR earned 45 paisa for every rupee it spent on passenger services (FE, 2024, March 22). There is no reason to believe that the under-recovery by IR will improve in the years to come. The percentage losses incurred by IR in various classes of travel between 2011-12 and 2014-15 were derived from Debroy and Desai (2016) as shown in Table 18. This was when IR was recovering about 55% to 60% of the expenditure in passenger services.

Table 18 Category-wise passenger business under recovery

1. Operating Loss: Mail/Express Classes (Non-Suburban Services) (%)					
Sl.	**Particulars**	**2011-12**	**2012-13**	**2013-14**	**2014-15**
A1	1AC	8.23	7.58	7.65	17.91
A2	First	NA	NA	NA	NA
A3	2AC	17.99	12.91	15.86	13.57
A4	3AC	-12.4	-10.49	-7.11	-12.89
A5	CC	1.63	4.04	12.03	10.07
A6	Sleeper Class	47.69	45.58	46.82	42.11
A7	Second Class	31.98	34.71	38.21	38.56

2. Operating Loss: Ordinary Trains (%)					
B1	First	NA	NA	NA	NA
B2	Sleeper	83.48	83.51	83.3	84.35
B3	Second Class	68.42	69.51	68.08	67.17
C	Average % under recovery	42.77	42.63	44.1	41.16

Source: Authors' calculation based on Debroy and Desai (2016)

It was estimated in 2014-15 that 3AC alone achieved the breakeven and achieved a profit of 12.89% (Debroy and Desai, 2016). However, with the implementation of the Seventh Pay Commission and increasing pension expenses, it is not known whether the 3AC class will achieve breakeven in FY2023-24. Even 1AC and 2AC incurred a loss of 17.91% and 13.57%, respectively, in 2014-15.

On the other hand, the average speed of various passenger services remains the same for many decades, which did not add value proposition to the passengers in terms of travel, although India opened its economy in 1991-92, and India has been witnessing a high growth rate since FY2003-04. Either IR or the passengers have been benefitting from the subsidy offered by IR to the AC rail passengers. If alternative, faster travel modes like HSR were available to AC rail passengers, they would happily move towards the same, leaving IR with the subsidy burden on non-AC passengers.

With premium charges, IR gains some profits from operating premium trains compared to Mail/Express trains. Despite the accusation that IR has been introducing more premium trains like VB than Mail/Express and ordinary trains, Mail/Express dominate the IR passenger traffic.

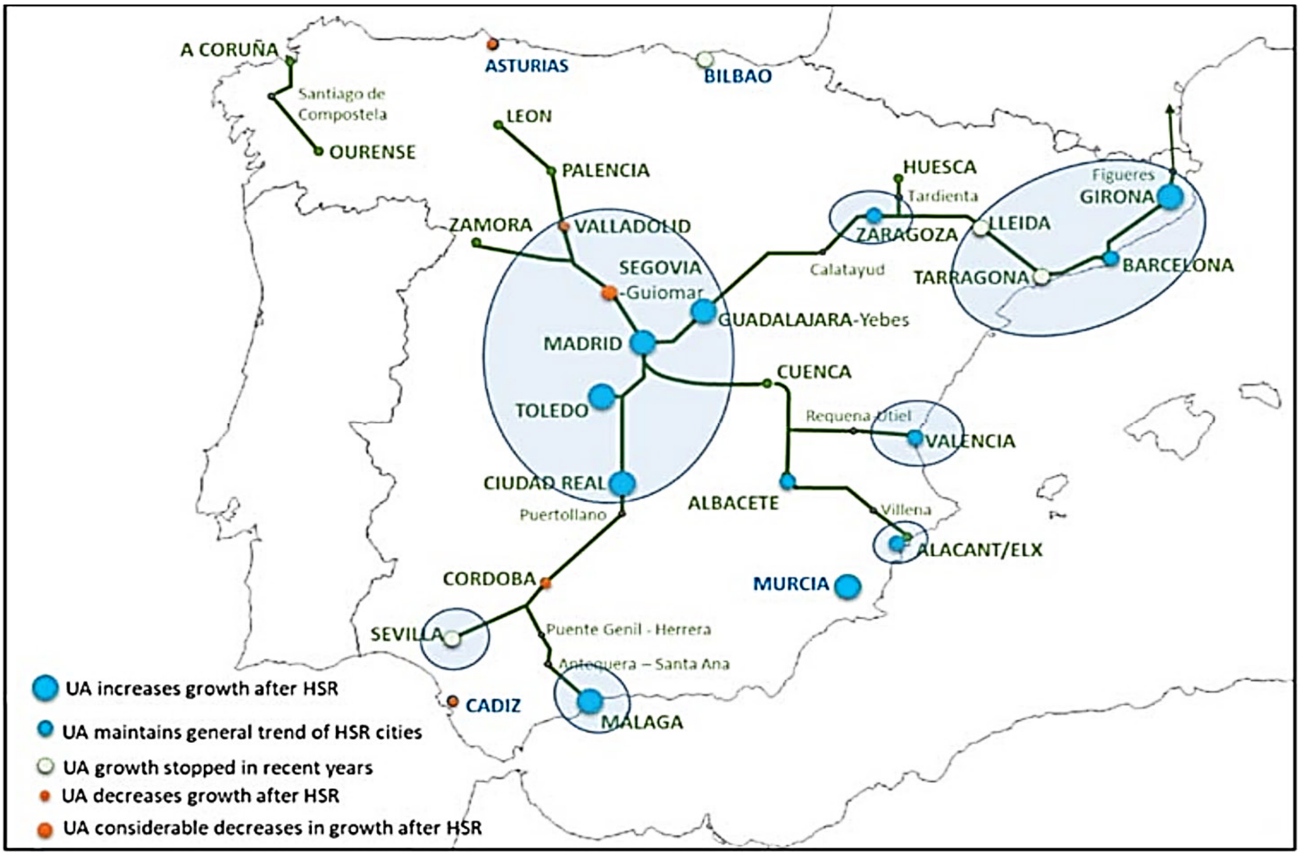
4.2 Widespread development

HSR development will facilitate decongestion in metropolitan and major cities and make development widespread. The urban population has increased to 31.3% in 2011 from 27.7% in 2001. When big villages get urban facilities, they are also accounted for as urban areas. Although this includes migration from rural areas to metropolitan cities, major cities, major towns, and smaller towns, the migration towards metropolitan cities and major cities has created enormous pressure on the civic amenities in these urban agglomerations. The HSR corridors may neither stop India from becoming more urban nor decongest the metropolitan cities and major cities, but the population in the urban spaces may become more distributed with faster rail connectivity. On the contrary, metropolitan cities and major cities may also see an influx of migration due to HSR rail connectivity reaching the central business district of these cities, thereby allowing more people to live in studio apartments in and around central business districts.

A case in point is Vapi versus Mumbai, where Vapi is located at 170 km. A resident property of 1000 square feet in Mumbai may cost about INR 3 Cr. - 3.5 Cr. at a rate of about INR 30-35 thousand per square foot; the same will cost about INR 30 lakh at a rate of about INR 2500-3000 per square foot in Vapi. The savings in terms of resident property would be about INR 3 Cr., and an interest rate of 6% will yield INR 1,50,000 as interest every month. Even if the HSR fare between Vapi and Mumbai will be about INR 1400 (175 km and Rs 8 per km) for a one-way trip, 45 trips in a month would cost about INR 63,000, saving INR 87,000 per month for those who sold their residential property in Mumbai and moved to Vapi. An equilibrium has been set by the lack of faster connectivity to the suburbs of major cities, and when faster connectivity in the form of HSR comes, it disturbs the equilibrium that has been already set and creates a disequilibrium. Once the HSR traffic ramps up, which will normally take about three years, as the international experience indicates, the disequilibrium accentuates and relieves the civic pressure of the Mumbai Urban Agglomeration. As a result, the prices of residential property in the distant suburbs of major cities also will increase substantially. This will lead to the development across the corridor, which has 10 intermediate stations, resulting in widespread development.

A good example of this is the growth of Urban Agglomeration (UA) with the introduction of HSR in Spain (Figure 2).

Figure 2 Growth of Urban Agglomeration in Spain with HSR



Source: Garcia (2019)

The UA of Madrid is extended up to Valladolid (210 km) in the north, Ciudad Real (200 km) in the south, and Guadalajara (65 km) in the east, with the HSR routes passing through these cities from Madrid. The UA of Barcelona is extended up to Girona (100 km) in the northeast, Lleida (160 km) in the west, and Tarragona (95 km) in the southwest, with the HSR routes passing through these cities from Barcelona. In addition to this, cities like Valencia, Malaga, Zaragoza, and Sevilla have also expanded their UA with HSR connecting these cities.

4.3 Possible USO funding

Financially successful HSR may provide Universal Service Obligation (USO) funding for conventional rail. With the huge subsidy for passenger services and contribution of Employer increased to 18.5% of the Basic plus DA in the Unified Pension Scheme compared to 10% of the Basic plus DA in the New Pension Scheme, the burden on expenditure will only increase for IR. Hence, USO funding from successful HSR projects to the conventional railway will go a long way in managing it.

The loss in Second class is the highest, followed by Sleeper class, 2AC and 1AC, in that order. It is certainly not possible to recover even a part of the losses incurred in Second class and Sleeper class, even if the fares are increased substantially. In the case of 2AC and 1AC, if the fares are substantially increased, it will push people to opt for car travel in the case of family travel, as it provides door-to-door connectivity, and the travel cost will be only on par with AC rail travel or air or luxury bus travel. In the case of Air travel, it reduces the travel time significantly compared to Conventional Rail, and the tickets booked in advance may become more competitive. The merger of Air India, Vistara, and Air Asia and the purchase of a huge number of fleets and widebody aircraft by both Tata Group and Indigo and the double digit CAGR domestic air traffic that has been witnessed in India since 2004, may provide economies of scale to these airlines and may offer fares relatively on par with increased AC rail fares. With such restrictions on fare increase, USO funding from successful HSR corridors to IR will help them to manage the finances.

The Ministry of Civil Aviation (MoCA) has been collecting a Universal Service Obligation (USO) fee from normal routes to subsidize the flights connecting smaller towns with smaller aircraft under the UDAN Regional Connectivity Scheme. The Ministry of Railways may follow the USO model of MoCA to subsidize part of the passenger service subsidy of conventional rail.

4.4 Potential employment opportunities

HSR construction creates huge employment. It is well accepted that the investment in infrastructure creates a multiplier effect. Since HSR is construction intensive, it creates huge employment opportunities at reasonable wage levels during the construction stage, which excludes RS manufacturing as shown in Table 19. In addition to the employment during construction, there will be employment in operating and maintaining the HSR corridor. With the RS manufacturing for HSR planned in India, both for internal consumption and export, the Micro Small and Medium Enterprises (MSME) that manufacture various sub-systems of HSR rolling stock, such as propulsion systems, seats, windows, and doors, will generate more employment.

Table 19 Employment generation for 2000 km of HSR development

Description	Direct employment Man months per km	Indirect employment Man months per km	Total employment Man months (2000 km)
Civil Works	2,979	165	62,88,000
Electrical	207	20	4,54,000
S&T	146	14	3,20,000
Total	3,331	200	70,62,000

Source: RITES (n.d.)

4.5 More options for faster travel

An advanced economy should have more options for travel between cities and within cities so that people can choose that which reduces disutility according to their estimation. With the telecom revolution of the last 20 years, India has achieved faster connectivity with huge penetration of mobile phone infrastructure and faster internet connectivity with fibre optic networks. UDAN (Regional Connectivity Scheme) and the construction of new airports and expansion of existing airports have partially helped to achieve faster transport connectivity. Although national highways and expressways developed in the last 25 years made road connectivity far superior to before 1998, they are not meant for as fast travel as HSR.

There is only one option for faster travel between cities now, and that is air. With the introduction of HSR in various corridors, passengers would have one more option to travel faster between cities in the distance range of 300 km-1500 km.

4.6 Spending pattern

As explained earlier, there is not much positive outcome in terms of increased throughput either in passenger or freight transport. Poor positive outcomes may be attributed to the following reasons.

- If a section with two lines with utilization of 180% has another line added, the utilization will become 120%, giving relief to the traffic department but may not increase the throughput.
- Although the electrification of running tracks increased from 41,038 in 2014-15 to 92,358 km in 2022-23, IR has not been able to capitalize on the increase in throughput as other constraints such as sectional speed limits, spatial signalling, manned level crossings, and differential speeds of various services have been playing havoc on the throughput of IR.
- The Railway Ministers before 2014 announced many new projects with no financial allocation for the same. These projects were initiated but resulted in huge time and cost overruns. IR incurred the highest cost overrun of INR 2.4 lakh Cr. among the total cost overrun of five lakh Cr. in March 2024 (BS, 2024, May 15). The main reasons identified for the inordinate delay are delays in land acquisition, obtaining clearances, tendering, contractual issues, and inadequate manpower; delays in technical approvals; law and order problems; and litigation by the concerned monitoring wing of the Central government. It was reported that the number of delayed projects related to infrastructure development in the railways has increased from 56 in 2022 to 98 in 2023. For instance, the Udhampur-Srinagar-Baramulla rail line project, sanctioned in 1995 at an original estimated budget of INR 2,500 Cr., is delayed by more than 21 years, with its cost escalating to INR 37,012 Cr. The Lalitpur-Satna-Rewa Singruli project, sanctioned in 1998 with an original estimated cost of INR 248 Cr., is now running delayed with the escalated budget touching INR 8,249 Cr. The new rail line from Byrnihat to Shillong, sanctioned in 2010 with an original budget of INR 906 Cr., is delayed, with the escalated budget reaching INR 8,324 Cr. (TNIE, 2023, June 12).

IR and its major PSUs have been bogged down by the operation and maintenance of existing railway systems and the organizational structure of IR has not been allowing IR officials to work on project management. By creating 18 zones and 68 divisions, IR has humungous and disaggregated organization structure that cannot function effectively. The projects which have been initiated but remain incomplete will not bring any revenue to the IR and social benefit to the country as well. Although such new project announcements stopped after 2014, the legacy effect has been lingering on.

Had IR spent 50% of INR 15 lakh Cr. on HSR, it would have developed about 1800 km of HSR. The point here is while spending on conventional rail, the incremental benefit for IR is very minimal and it is like spreading the investment too thin across too many things.

4.7 Better opportunity for Atmanirbhar Bharat

HSR development is a good opportunity for Atmanirbhar Bharat. Although the first HSR project is 80% funded by JICA and technically supported by Shinkansen, NHSRCL engineers learned a lot about the execution and commissioning of HSR and would learn even more when the first HSR corridor is commissioned and operated. NHRSCL will get only 18 train sets from Japan, and the remainder will be manufactured in India. The ecosystem for manufacturing various equipment and components for HSR in India would create positive externalities for the rail industry.

The manufacturing of High Speed Rolling Stock from conception, design, manufacturing and maintenance provide huge opportunities for local manufacturers to enter into cutting edge technologies and supply these items. The value addition at each stage is much more in High Speed Rolling Stock compared to conventional rail Rolling Stock and this will add high end jobs in the rail industry.

4.8 Savings in travel time and energy

HSR reaches the central business district, thereby reducing access and egress travel time and energy. This may also reduce access and egress travel costs. Airlines (if there are even two airports in a city like Delhi) can reach only the extreme outskirts of the city, whereas HSR may reach the city centre and many captive points of passenger traffic, reducing access and egress time and waiting time significantly, thereby bringing the end-to-end travel time on par with airlines.

4.9 Energy security

When passengers move from air to HSR, the use of crude oil-based energy will be reduced, and this will ensure energy security to that extent. On average, India imports about 87% of its crude oil demands from foreign countries. Although the penetration of EVs would reduce the dependency on crude oil substantially, the air sector, which has been growing at a double-digit rate since 2004-05, demands more aviation turbine fuel. Unlike EVs, which require batteries to store electricity, HSR uses electricity directly from the grid, thus saving the negative externalities associated with the disposal of batteries. Although coal-based electricity also creates a lot of negative externalities, there is enough coal in India, and hence India's oil vulnerability would reduce if HSR is developed across India and thereby improves energy security.

4.10 Targeting Net Zero economy by 2070

HSR will facilitate a Net Zero economy by 2070. Although, at present, India depends on fossil fuels for 70% of its electricity needs, investment in renewable energy has been stupendous since 2014-15. India would also like to achieve 50% of its electricity needs from renewable energy. Since HSR operates on electricity, unlike Air, and with India aiming to achieve at least 50% electricity from non-fossil fuels by 2070 from the current level of 20%, the growth and contribution of HSR in meeting passenger demand would facilitate a net-zero economy by 2070.

4.11 Leapfrogging to higher rail travel speed

HSR will enable leapfrogging to an average speed of 240 kmph by rail. For instance, there are some sections in IR that cannot be straightened because of the difficulty in creating new straight right of way in HDN1 and HDN3 and other conventional railway lines. For instance, in the Mumbai-Ahmedabad route, the speed can be enhanced only in Virar-Ahmedabad, and the Mumbai Central-Borivali and Borivali-Virar sections will continue to run at a speed of 100 kmph and 110 kmph, respectively. With a maximum speed of 130 kmph, the VB train between Mumbai and Gandhi Nagar attained an average speed of 82 kmph, whereas with a maximum speed of 160 kmph, it would reach an average speed of 93 kmph. The introduction of Wheel-on-Rail HSR would achieve an average speed of 197 kmph to 247 kmph depending on the number of stops, which can never be achieved by conventional rail rolling stock with a design speed of 220 kmph. As per the current phase of growth, India is poised to become the third-largest economy in the world well before 2030. However, reaching an average speed of 240 kmph with a maximum speed of 320 kmph is what India, as the third-largest economy, should aim for. HSR development is the key to achieve this.

4.12 Promoting Indigenous technology

HSR development will give an opportunity for developing cutting-edge technology indigenously. India depends on developed countries for cutting edge technologies across sectors, whether it is electronics, telecommunication, software, electric vehicles, solar and wind energy, or heavy machinery. Although many multinational firms have established offshore R&D centres in India, India has not been the originator of innovation, although Indians in India and abroad play a crucial role in developing cutting-edge technology. Even on rail technology, though indigenous spatial signalling systems were developed, in-cab signalling systems on par with ETCS1 or ETCS2 were not developed, although some breakthrough was made in KAVACH, which can be upgraded to in-cab signalling systems with further research and development. Swiss technology was first imported for manufacturing coaches, now called "ICF technology," as ICF Chennai manufactured it to begin with. Then railways moved to LHB technology of German origin, which had a better coupling system between coaches and that ensured that if a train was involved in an accident, the coaches do not get thrown or jump into one another as much as ICF technology coaches would. The Vande Bharat train technology and the KAVACH were also patented by Indian Railways (Kabirdoss. 2024, March 14). The number of patent applications by Indian firms, both public sector and private sector, on rail safety has been increasing from a few tens in 2003 to more than 500 in 2022 (Rana S.S. & Co. 2023, August 11). When India develops its indigenous technology on all dimensions of HSR, the number of patents per year may be in thousands.

The Ministry of Railways awarded a contract for design, manufacturing and commissioning of two high speed trainsets, each comprising eight cars at a contract value of INR 866.87 Cr. (Mishra, 2024, October 16). This is to make India self-reliant on rolling stock dimension of High Speed Rail.

4.13 Dignity of travel and ease of living

A major component of ease of life is enhanced by travel convenience provided by HSR. The disutility is the time, energy, expense, and penalties a traveller incurs while travelling; the utility is arriving at the destination from the departure point. People transfer from the old mode to the new mode if it offers less disutility in aggregation, which is the fundamental idea of the discrete choice model that assesses the likelihood of this transition. When the Generalised Cost of Travel (GCT), which includes end-to-end price, end-to-end travel time, switching and inconvenience, is lower, the utility is at its highest for people who prioritise cost. However, the value of travel time has increased and will continue to increase as Indians' per capita wealth rises across all regions. The ease of travel is associated with significantly reduced travel time with better ride quality and easy and seamless switching between modes.

With HSR, career women could travel between cities with ease. Women who travel for work between cities have to take the luxury bus, the train, or the aeroplane, depending on their financial condition. They can finish the trip in one day as long as it takes a day of labour. HSR would permit them to travel between cities in addition to by air to attend client meetings and field trips if the task could be completed in a single day. This would allow them to progress in their occupations more successfully without compromising their responsibilities at home. They are also able to start early in the morning and return late at night because of the HSR's travel service between city centres.

4.14 Balancing the conventional rail travel needs

Apart from AC classes, there are second-class and sleeper passengers that badly need access to rail travel. To avoid the backlash from non-AC passengers snowballing into a law-and-order problem, IR may have to move AC passengers to HSR at the earliest. As shown in Table 3, the CAGR of sleeper class and second class between 2005-06 and 2022-23 was 5.11% and 3.84%, respectively, in Mail/Express trains. With the growth of the road network, second-class travel and sleeper class travel by Ordinary trains have been disappearing, as these trains operate at an average speed of 35 kmph. The CAGR of second class at 3.84% in Mail/Express trains (at an average speed of 55 kmph) compared to negative growth in Ordinary trains (at an average speed of 35 kmph) is an indication that even general compartment passengers look for faster travel. The ticket sales of second-class passengers indicate that Mail/Express trains have been preferred by passengers over ordinary trains when passengers have both the options to travel to their desired destination (Ramakrishnan, 2020).

The patronage for ordinary trains has been decreasing for at least two reasons. The first reason is that ordinary trains operate on short to medium distances and do not pass through many states like Mail/Express trains. The lead (average distance people travel) has been increasing with people travelling through various states, as in the case of migrant workers, Mail/Express trains are only available for such lengthy trips. The second reason is that even for short and medium-distance trips, the second-class passengers have not been preferring ordinary trains, as their average speed of about 35 kmph is lower than the average speed of 55 kmph of Mail/Express trains. The second reason is that the road connectivity has improved a lot, and for short to medium distances, passengers prefer it either on common carrier mode like buses, personal vehicles, or hired vehicles.

However, the demand for the waitlisted non-AC passengers is about 10%-25% in relation to less than 10% in AC rail classes in 2018-19 (RITES, 2020). When AC travellers have other options like Volvo buses, personal cars, and air, it can be surmised that they don't have to become desperate, especially when they know that the chance of getting a confirmed ticket is slim.

In 2023, passengers and political constituencies complained that the sleeper coaches and general compartment coaches have not been increased as much as 3AC coaches. IR gave a rebuttal that there was no reduction in non-AC coaches (HT, 2023, November 17). This backlash from non-AC passengers makes it difficult for IR to increase the AC coaches now, as the demand for non-AC travel continues to dominate the narrative of IR policy on train services.

Migrant workers who want to travel by sleeper coaches also find it difficult to get tickets since the number of migrant workers increased exponentially in the last two decades (Navya, 2023). For example, the number of services available for 30 lakh migrant workers of Kerala to their respective states is only 14 services daily, which included all classes (Kallungal, 2024).

As per census 2011, the total number of interstate migrant workers in the country comprised 4.14 Cr. in 2011 (PIB, 2023). For the last few years, there have been many reports on the passengers with unconfirmed tickets and passengers of second class (general compartments) occupying the AC classes and denying entry to the passengers who have confirmed AC tickets (Ghosh, 2024). Although this may be treated as a violation of a few passengers here and there, the situation has been becoming alarming as the frequency of these events has increased. When many passengers with no proper ticket to travel in that AC coach gather inside, it becomes virtually impossible to deploy the force to evict the passengers and allow the passengers to board the train and travel till their destination. This issue is an outcome of a lackadaisical approach that has been followed by IR for many decades now (PIB, 2023). As per Census 2011 and NSSO estimates, the total number of interstate migrants in India stands at around INR 6.5 Cr. in 2020. Most of the migrant workers travel from Northeastern states, West Bengal, Odisha, Bihar, and UP to states like Kerala, Karnataka, Tamil Nadu, Maharashtra, and Gujarat seeking employment opportunities. They also travel to their native places once or more in a year for festival season, elections, family functions, local festivals, and harvesting.

Debroy and Desai (2016) highlighted that in FY2014-15, out of the total operating loss of INR 27,799 Cr. from the non-suburban services, second class (Mail/Express and ordinary trains) alone constituted INR 18,736 Cr. The sleeper class constituted INR 9,040 Cr. and the remaining by the AC classes. 3AC alone generated a profit of INR 882 Cr. Sensing the huge loss incurred by the IR on second class and sleeper class, IR manufactured and added more 3AC coaches as the demand for AC class travel has been higher than non-AC PRS and UTS classes and manufactured and added less sleeper and second-class compartments. This was the right strategy by IR to meet the increasing demand for 3AC travel and to reduce the losses on passenger services for more than a decade. Though this practice has continued for more than 20 years now, the number of seats and berths available for second class and sleeper classes did not grow as much as it should have grown, as shown in Table 20.

Table 20 Supply of AC seats versus non-AC seats in IR

Year	Berths /seats (All trains)				Share (%) (All trains)		
	AC (PRS)	Sleeper (PRS)	2nd class (UTS)	Total	AC	Sleeper	2nd class
2010-11	3,51,800	10,55,400	28,44,300	42,51,500	8.27	24.82	66.9
2021-22	9,28,610	17,24,561	34,39,080	60,92,251	15.24	28.31	56.45
CAGR % between 2010-11 and 2021-22	9.22	4.57	1.74	3.32			

Source: Author's calculation based on Annual Account Statements of IR 2010-11 and 2021-22

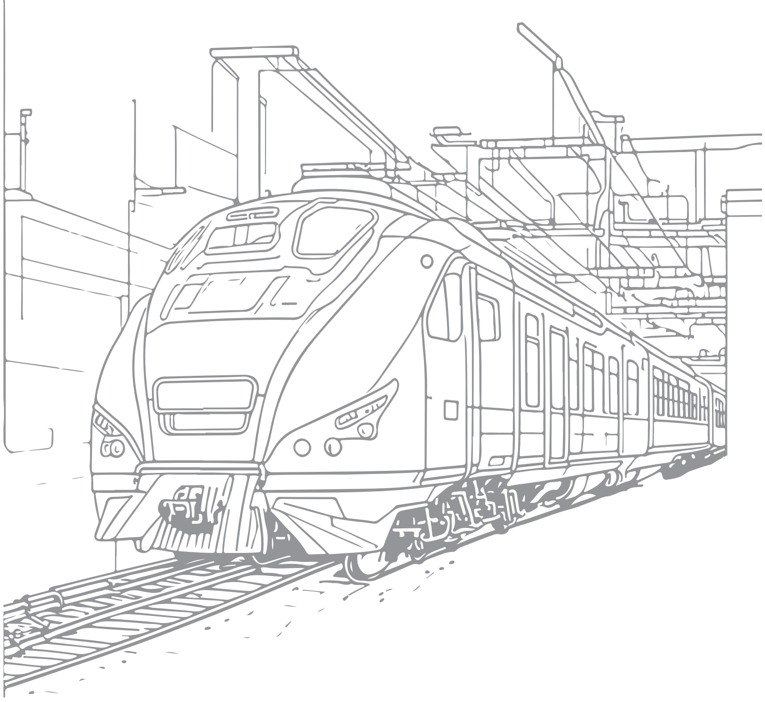
Before making key inferences, there is a caveat: The number of berths/seats of AC, sleeper and second class does not automatically translate into passenger traffic as this data is not an absolute measure of passenger traffic. There are many factors that will moderate with number of berths/seats available such as speed of the train, average lead of various classes and utilization of various types of coaches.

- The Second class (general compartment) seats constitute more than 50% despite the IR's focus to increase AC class coaches. The sleeper coaches also increased significantly although not as much as AC classes.
- IR provides a facility for auto upgradation for all PRS classes, thereby if 1AC seats are vacant, 2AC waitlisted passengers are upgraded to 1AC berth with no additional cost to the passengers, if 2AC seats are vacant, 3AC waitlisted passengers are upgraded to 2AC berth with no additional cost to the passengers and if 3AC seats are vacant, sleeper waitlisted passengers are upgraded to 3AC berth with no additional cost to the passengers. Unless the capacity available is more than the demand in some AC classes, it is virtually impossible to actualize the auto upgradation scheme.

The point is only with the increase in the rail network that can carry passengers and freight faster, the ever-growing demand for rail travel either by conventional or HSR mode may be met. When HSR is available in some O-D pairs, the passengers who moved out of conventional AC class travel to HSR would give enough opportunity for IR to carry more Non-AC PRS and UTS passengers.

The general rake pattern as per IR is there will be eight AC coaches, 12 sleeper coaches and two second class coaches in a rake of 22 or 24 coaches. Even if three AC coaches out of eight AC coaches moves towards HSR, three more second class or sleeper coaches may be added to each Mail/Express train.

CHAPTER 05



The Future With HSR

The future with HSR consisted of the following themes.

- NRP's framework in identifying HSR corridors
- Modifications required in NRP's framework
- The prioritization of HSR routes between 2025 and 2035
- The HSR O-D pairs identified as per the rule of thumb
- Balancing the criteria for prioritizing HSR corridors
- Why India has no choice but to develop HSR Tech domestically?
- How should India develop all aspects of High Speed Rail Technology on its own?
- National High Speed Rail Technology Corporation for indigenous development of HSR

5.1 NRP's framework in identifying HSR corridors

To determine the level of demand for high-speed rail between any two city pairs, the NRP created a ranking system based on an index of five factors. These are the five requirements.

1. The city population of the origin or destination city should be more than 10 lakhs.
2. The origin and destination cities are separated by 300 km to 700 km.
3. The GDP of the cities enroute.
4. High level of congestion.
5. Passengers flow between city pairs by AC rail and air.

Based on the above criteria, the phased implementation of HSR corridors was arrived at by the NRP, as listed in Table 21.

Table 21 Proposal for the phased implementation of HSR corridors

Phasing	Total length	Routes
By 2031	2521 kms	Delhi Varanasi via Ayodhya 855 km *
		Varanasi to Patna 250 km (New)
		Patna to Kolkata 530 km (New)
		Delhi Udaipur Ahmedabad 886 km *
By 2041	1473 kms	Hyderabad Bengaluru 618 km (New)
		Nagpur Varanasi 855 km (New)
By 2051	3485 kms	Mumbai Nagpur 789 km *
		Mumbai Hyderabad 709 km *
		Patna Guwahati 804 km (New)
		Delhi Chandigarh Amritsar 485 km *
		Amritsar-Pathankot-Jammu 190 km (New)
		Chennai to Mysuru via Bengaluru 462 km *

* As per National Infrastructure Pipeline (NIP)

Source: *(IR, 2021)*

The key shortcomings of the phasing of the HSR as envisaged by the NRP are as follows:

- The phase up to 2031 is lopsided only providing connectivity in Delhi-Kolkata and Delhi-Ahmedabad. Prioritizing these two corridors is on the belief that if HSR is operationalized in these two routes, the congestion on conventional rail lines will reduce substantially. However, the rail traffic flow of the passengers in Delhi-Kolkata route indicates that it is dominated by non-AC passengers, and this may not change drastically at least for a decade.
- The HSR corridors "By 2041" is less ambitious as once India develops 3000 km of HSR by 2031, it must be able to speed up the construction of HSR and hence can aim for more than 3000 km easily.
- The target of 3485 km for "up to 2051" is good, but the NIP corridors of Delhi-Chandigarh-Amritsar and Chennai-Mysuru via Bengaluru, which have exceptional potential to be taken up immediately (as recommended by more than one report) cannot be pushed "up to 2051".
- New corridors such as Hyderabad-Bengaluru 618 km and Nagpur-Varanasi 855 km have been given sudden push to be completed by 2041, when the diagonals of the golden quadrilateral such as Mumbai-Kolkata and Delhi-Chennai have found no place in the phasing list.

India may have to develop its indigenous technology to reduce the cost of HSR construction significantly, which is about INR 400 Cr. per km, when technology is imported. This process may take at least about five years, and hence it is better to have a moderate target of "By 2031."

However, the election manifesto of the BJP for the 2024 general elections corrected the lopsided phased plan of HSR implementation, which is the ruling dispensation now, by stating that "We are constructing the first bullet train corridor in the country. Using the experience gained so far, we will initiate feasibility studies for Bullet Train Corridors in North, South, and East India," indicating that the HSR development will be across the regions.

5.2 Modifications required in NRP's framework

The modifications required in the framework used by the NRP for HSR corridors are listed below.

5.2.1 Existing travel pattern

The existing travel pattern of the population matters more than mere population. The larger the population of the cities enroute, the greater the possibility of achieving higher ridership for HSR. However, there is a caveat: if the population's existing travel pattern is predominantly non-luxury modes such as ordinary buses and non-AC rail classes, the higher population may not translate into higher ridership.

5.2.2 Per capita GDP of the cities

While population will moderate the cities' GDP, a more accurate metric would be GDP PPP per capita, which is calculated by summing the GDP of all major cities along the route (where HSR stops will be provided) and dividing the result by the population of all the cities along the route. The moderation of GDP with population gives the financial muscle of the people residing in the cities that the HSR corridor would be traversing through, so that when HSR is given an option for faster travel, they would grab it.

5.2.3 Congestion factor

The high level of congestion in the IR network does not guarantee the demand for HSR. The rail congestion is due to many reasons. Insufficient network, poor throughput due to block signalling that permits only one train in a block, differential speeds that arise out of different speeds of different trains, inadequate capacity of the terminals, manned level crossings, and huge passenger flows from non-PRS and non-AC passengers and huge rail freight traffic could be some of the reasons for the congestion in the network. Unless it is scientifically estimated that an HSR corridor gets enough ridership from luxury modes such as AC rail classes, Air, Volvo buses, and cars, the congestion in conventional rail networks cannot disappear with the construction of an HSR corridor. HSR corridors may operate sub optimally while conventional rail lines may remain congested, which may be the outcome of prioritizing HSR corridors based on rail congestion.

5.2.4 Expected ridership

Passenger flow by AC rail and air alone is not sufficient to measure the expected ridership. The modal shift to HSR will come from luxury rail, air, luxury buses, and cars. Luxury buses have emerged as the preferred mode for passengers since 2004 when Volvo entered the Indian market, which charges less than air but on par with AC rail. Although the speed of luxury bus travel is on par with rail travel, it provides comfort on par with AC sleeper classes on rail. In the case of luxury buses such as Volvo and Scania and luxury rail, the HSR fare would be about twice that of a luxury bus, but the end-to-end travel time would reduce by almost 70%. With the enormous growth of national highways and motorways, intercity trips by car have become the norm. Without considering luxury bus and car travel, the prioritization of HSR corridors will be incomplete.

5.3 The prioritization of HSR routes between 2025 and 2035

There is a two-step process in deciding the prioritization of HSR corridors.

First step in identifying better HSR corridors

The first step is to identify the best routes that look at the following criteria holistically as per Gravity Model, without going into travel pattern or ridership estimation for a high-speed and high-cost transportation system, whether it is HSR, Maglev or Hyperloop.

- Population of the cities enroute including origin and destination of the corridor. The more the population, the better it is. This brings the weight. Preferably, one or more cities should have huge population, and other cities should have a moderate population as in the case of Ahmedabad-Mumbai corridor, where Mumbai has the huge population and Ahmedabad, and Surat has moderate population and Vadodara has lesser population.
- The combined per capita GDP of the cities enroute including origin and destination of the corridor. The more the per capita GDP, the better it is. This brings the sharpness.
- The distance of the corridor. However, within a corridor, there may be many O-D pairs some of them are of short distance, medium distance and long distance. The shorter and medium distance corridors may bring more travel than long distance travel,

as people prefer to travel with shorter time and reduced price for their economic opportunities.

- In addition to this, there are some other factors like tourist attraction and pilgrimage that can also add up to the ridership. For instance, Delhi-Ayodhya-Varanasi-Kolkata HSR corridor (or a spur to Ayodhya) may bring pilgrims across the Gangetic belt to Ayodhya and Varanasi

There is a caveat. None of these criteria should be seen in isolation. The huge population alone cannot bring enough ridership to the high-speed transportation system, as many of them may travel by cheap options. For instance, a high-speed transportation system connecting Agra and Patna may not bring enough ridership, if it is not connected to Delhi. However, the huge population along the route could bring more passengers to high-speed transportation system, even if 10% of the population have the willingness and affordability to pay for faster and costly travel. Or when the per capita GDP increases substantially due to economic development, the corridor becomes financially viable very quickly. The combined per capita of the cities cannot alone bring enough ridership to HSR. For instance, Gurugram and Pune have the highest per capita GDP, but unless otherwise they become a part of the bigger high speed transportation network, they don't bring enough ridership. The shorter or medium distance may not bring enough ridership to high-speed transportation system. For instance, Mumbai-Delhi carries one third of the total domestic traffic, although they are 1400 km apart. Based on the first step, the four main corridors have been analyzed for the above criteria as shown in Table 22.

Table 22 Analysis of main HSR corridors as per Gravity Model

Main HSR corridor	Distance (km)	Cities considered for Combined Total	Combined values		
			Population 2022	Per capita GDP 2022 (INR)	Per capita GDP PPP 2022 (USD)*
Delhi-Sonipat-Panipat-Karnal-Ambala-Chandigarh-Ludhiana-Jalandhar-Amritsar	566	Delhi, Chandigarh, Ludhiana, Jalandhar & Amritsar	3.79	6,71,280	28,307
Delhi-Rewari-Jaipur-Ajmer-Jodhpur-Pali/Beenja-Palanpur-Mehsana-Gandhi Nagar-Ahmedabad	876	Delhi, Jaipur, Ajmer, Jodhpur & Ahmedabad	4.61	6,90,640	29,123
Delhi-Agra-Lucknow-Ayodhya-Varanasi-Patna-Kolkata	1,670	Delhi, Agra, Lucknow, Varanasi, Patna & Kolkata	5.76	6,77,760	28,580
Mumbai-Navi Mumbai-Pune-Satara-Kolhapur-Belagavi-Dharwad-Davengere-Tumkuru-Bengaluru-Tirupati-Chennai	1,366	Mumbai, Pune, Belagavi, Dharwad, Bengaluru, Tirupati & Chennai	5.22	8,80,160	37,115
Total	4,478				

* USD-INR Conversion rate and Purchase Power Parity were taken as 83 and 3.5 respectively

Source: *IR (2021)*

The key inferences from Table 22 are as follows.

- The per capita GDP PPP of three main corridors is at least USD 28,000 and the Mumbai-Chennai corridor is at least USD 37,000 in 2022, which is much higher than national average. By the time, the construction of HSR starts, the per capita GDP PPP would have increased by at least 20%.
- The total population of the major cities of these corridors are about INR 3.8 Cr. to 5.8 Cr., equal to the population of a large European country.
- Delhi-Amritsar is a medium distance corridor and Delhi-Ahmedabad, Delhi-Kolkata and Mumbai-Chennai are long distance corridors. Execution of a long-distance corridor can be done in stages, and it is better to identify the best sub-corridors of a long-distance corridor that needs to be prioritized.

Despite these corridors meeting the requirements as per Gravity Model, only when the ridership of these corridors is established by one or more feasibility study and DPR, the suitability of these corridors may be established.

The second step in estimating the financial viability of HSR corridors

Although the financial viability of each HSR corridor varies depending on the expenditure involved in the construction of HSR, the rule of thumb is that if the HSR corridors do not recover the investment in the first 15-20 years of commercial operation, then they will never recover the investment made as O&M costs pertaining to rolling stock, signalling, and traction recur at regular intervals. According to de Rus and Nombela (2007), "High rail investment is difficult to justify when the expected first-year demand is below 8-10 million passengers for a line of 500 km." Without estimating the financial viability of the corridor by estimating the expenditure and revenue over the period of construction and operation, the rule of thumb given by de Rus and Nombela (2007) may be modified more stringently, as if the end-to-end passengers of an HSR corridor exceeded 80 lakhs in the first year of operation, it would become financially viable and recover the cost. However, this rule of thumb may not be applicable for HSR corridors, which involve higher expenditure due to terrain and other such factors. Although the consortium of Systra-RITES-Italfer generated a feasibility report for the Pune-Mumbai-Ahmedabad High Speed Line, the Railway Board in March 2013 decided to drop the Mumbai-Pune section as the ghat section between Pune and Mumbai would escalate the budget for the project. although the Pune-Mumbai section would have met the rule of thumb and added more passengers to the Ahmedabad-Mumbai HSR corridor, which is under construction. Subsequently, when JICA prepared the DPR, it included only the Mumbai-Ahmedabad section.

5.4 The identified HSR O-D pairs

The first HSR corridor between Ahmedabad and Mumbai began in 2017. Although two years of Covid can be attributed to the delay in the project, it is expected to be commissioned for its full length of 508 km in 2029, which means the first HSR project will take about 12 years. With the learnings from the first project, Indian engineers may construct subsequent projects faster. However, international experience shows that a minimum of seven years is required to construct an HSR corridor. The phase of "By 2031" is too ambitious to be realistic. Hence, the period of the second phase of HSR development is chosen as 2025-2035, and FY2036-37 will be the commissioning of the second phase of HSR corridors and the first year of commercial operations.

The expected end-to-end passengers in FY2036-37 for various HSR corridors identified in Table 23 were estimated from various feasibility studies and reports that were submitted to the Indian Railways.

Table 23 HSR corridors operational by 2036-37

Description	HSR Corridors	Distance (km)	End-to-end passengers 2036-37	
			Daily	Yearly
Main corridor 1	Delhi-Rewari-Jaipur-Ajmer-Jodhpur-Ahmedabad-(Mumbai)*	934	2,09,315	7,63,99,975
Sub corridor **	Delhi-Jaipur via Gurugram	270	38,448	1,40,33,520
Main corridor 2	Chennai-Mumbai via Tirupati, Bengaluru, Tumkuru, Davangere, Dharwad, Belagavi, Kolhapur, Satara, Pune, Navi Mumbai with a spur to Goa	1,366	65,703	2,39,81,595
Sub corridor	Chennai-Bengaluru (with a spur to Tirupati from Chittoor)	410	39,127	1,42,81,355
Sub corridor	Chennai-Bengaluru direct (no spur to Tirupati from Chittoor	340	32,020	1,16,87,259
Sub corridor	Pune-Mumbai	150	27,684	1,01,04,660
Main corridor 3	Delhi-Sonipat-Panipat-Karnal-Ambala-Chandigarh - Ludhiana-Jalandhar-Amritsar	665	49,115	1,79,26,975
Main corridor 4	Delhi-Agra-Lucknow-Varanasi-Patna-Kolkata	1740	31,985	1,16,74,525
Sub corridor	Delhi-Agra-Lucknow-Varanasi-Patna	1,150	30,394	1,10,93,810
Sub corridor	Delhi-Agra-Lucknow-Varanasi	890	29,551	1,07,86,115
Sub corridor	Delhi-Agra-Lucknow	442	26,207	95,65,555

* This corridor ridership includes all O-D pairs except the O-D pairs in the stretch of Ahmedabad-Mumbai

Source: Author's calculation from HSRC (2016), HSRC (2017), HSRC (2018), TSDI and Tractabel (2018)

The key inferences from Table 23 on main corridors are as follows:

- Essentially there are four main corridors that pass the ridership criteria of 95 lakh end to end passengers. They are Delhi-Rewari-Jaipur-Ajmer-Jodhpur-Ahmedabad-(Mumbai), Chennai- Mumbai via Tirupati, Bengaluru, Tumkuru, Davangere, Dharwad, Belagavi, Kolhapur, Satara, Pune, Navi Mumbai with a spur to Goa, Delhi-Sonipat-Panipat-Karnal-Ambala-Chandigarh-Ludhiana-Jalandhar-Amritsar and Delhi-Agra-Lucknow-Varanasi-Kolkata. These four main corridors designated as 1,2,3 and 4 in terms of expected ridership.
- Once Delhi-Rewari-Jaipur-Ajmer-Jodhpur-Ahmedabad-(Mumbai) is connected by HSR, the end-to-end passengers in this HSR main corridor 1 will be so huge that it may well become the second HSR corridor that carries the maximum passengers in the world after Tokaido Shinkansen. The reason for this is that it connects the financial capital with the national capital. This route carries about 30% of the domestic air passenger traffic. Even a 30% shift to HSR from single hop air travel between Mumbai and Delhi would add substantial traffic to HSR. In addition to this, this corridor covers tourist spots in the cities of Jaipur, Ajmer, Jodhpur and industrial towns of Surat, Vadodara and Ahmedabad. In addition, the sub-corridors of Delhi- Jaipur, Delhi-Ajmer, Delhi-Jodhpur and Ahmedabad-Mumbai, Vadodara-Mumbai and Surat-Mumbai will also significantly contribute to this huge ridership. This should be the topmost corridor that takes precedence over all other corridors.
- The main corridor 2 of Mumbai-Chennai may generate twice that of minimum ridership that justifies the development of this HSR corridor. The sub corridors considered here are Mumbai-Pune, Bengaluru-Chennai with a spur to Tirupati. Mumbai-Bengaluru has been poorly served by IR with about 25 hours of travel time for 1120 km and hence the intercity travel has been better served by air with an annual passenger of about 36 lakhs both directions together in 2022-23. The shift from air, AC rail and luxury bus will also add to the HSR ridership.
- The main corridor 3 of Delhi-Sonipat-Panipat-Karnal-Ambala-Chandigarh-Ludhiana- Jalandhar-Amritsar will also be a profitable HSR corridor. The ridership comes from the movement of passengers from various places enroute to the destination of Amritsar and back, as people in these regions do visit the Golden Temple at regular intervals. At present, it is mainly served by personal cars, air, luxury bus and AC rail modes. Any partial execution of the HSR either between Delhi-Chandigarh or Chandigarh-Amritsar would not bring enough ridership to this corridor.
- The main corridor 4 of Delhi-Agra-Lucknow-Varanasi-Patna-Kolkata would be financially viable but may not generate excess revenue and windfall profits as the ridership will be just above the yardstick that we prescribed here.
- A sub-corridor is a part of main corridor, or a main corridor consists of many sub corridors. For instance, Delhi-Agra-Lucknow is the sub-corridor of the main corridor of Delhi-Agra-Lucknow-Varanasi-Patna-Kolkata.

- Some of the sub-corridors of these four main corridors will have ridership beyond the threshold level and can be financially viable independently. For instance, in the main corridor 1 Delhi-Ahmedabad (which will provide connectivity up to Mumbai with Ahmedabad-Mumbai HSR corridor under construction), Delhi-Jaipur via Gurugram will not only be financially viable but will have a ridership almost twice that of threshold ridership. There are no other sub corridors that can be independently financially viable in main corridor 1.
- In the main corridor 2 of Mumbai-Chennai, Bengaluru-Chennai without a spur to Tirupati will have a ridership well above threshold level and with a spur to Tirupati will have a ridership which is about 1.5 times that of threshold level. A spur of 70 km from Chittoor to Tirupati would not only add significant ridership to Bengaluru-Chennai HSR corridor, but also facilitates the quick arrival to Tirupati from Chennai and Bengaluru and quick departure from Tirupati to Chennai and Bengaluru. The other sub-corridor of Mumbai-Pune will also have ridership above the threshold. As the construction cost of this corridor may be higher, its financial viability needs to be checked independently. Nevertheless, the seamless connectivity to the contiguous Mumbai-Ahmedabad HSR corridor will add passengers to Mumbai-Pune and Mumbai-Ahmedabad HSR corridors.
- In the main corridor 3 of Delhi-Agra-Lucknow-Varanasi-Patna-Kolkata, the three sub-corridors of Delhi-Agra-Lucknow, Delhi-Agra-Lucknow-Varanasi and Delhi-Agra-Lucknow-Varanasi-Patna will have ridership beyond the threshold level. However, the sub-corridors will not have enough ridership if it is not connected to Delhi. That is Lucknow-Varanasi, Lucknow-Varanasi-Patna, Varanasi-Patna, Patna-Kolkata will not have enough ridership to justify its construction independently. Either a spur to Ayodhya or Delhi-Lucknow-Ayodhya-Varanasi will also have ridership beyond the threshold level.

The moot question is how the above corridors may perform in comparison with the Ahmedabad-Mumbai HSR corridor. The JICA DPR assumed that FY2023-24 will be the first year of operation, and it was estimated that this corridor will have 40,000 daily passengers with an average travelling distance of 300 km (against the total distance of 508 km), which is equivalent to 23,622 end-to-end passengers, which corresponds to 86,22,047 passengers per year. The JICA DPR estimated that there will be 2,02,000 daily passengers (which is about five-fold that of the first year of operation in a thirty-year period) in 2053-54 with an average travelling distance of 300 km, which is equivalent to 1,19,291 end-to-end daily passengers, which corresponds to 4,35,41,339 end-to-end passengers per year. It was extrapolated that there will be 48,436 end-to-end daily passengers, which corresponds to 1,76,79,142 passengers per year in 2036-37 (JICA, 2015, June).

If the Ahmedabad-Mumbai HSR corridor is fully commissioned by 2028-29, as per JICA DPR, the end-to-end daily passengers will be 30,946 and 1.13 Cr. passengers (JICA, June 2015). So, the first corridor, even though delayed by about five years, will still have ridership above the threshold level.

5.5 Balancing the criteria for prioritizing HSR corridors

For a corridor to be selected for HSR development between 2025-26 and 2035-36, it must meet the following criteria in that order:

- HSR corridors that can generate huge ridership, revenue, and profits.
- HSR corridors that have a key O-D pair of about 300 km - 800 km distance. These are best in terms of project implementation.
- The selected HSR corridors should represent all regions, ceteris paribus.
- Development of contiguous HSR corridors.
- EIRR can never be the criteria for HSR development.

5.5.1 HSR corridors that can generate huge ridership

HSR development, operation, and maintenance may become a white elephant when the corridors are not chosen based on expected ridership done through rigorous ridership studies. If the corridors are chosen with due diligence and extreme caution, they may bring huge profits.

Although, as of 2024, there are about 59,000 km of HSR corridors that are in commercial operation, only three HSR corridors in the world have generated windfall profits (UIC, 2023, December).

The Tokyo-Osaka HSR (Tokaido) generated such enormous profits that Japan was able to construct other HSR corridors, which are not financially viable in their first year of operation, from the proceeds of the Tokaido Shinkansen. Japan went for commercial operation of its Tokaido Shinkansen in 1964-65 with passengers of 1.1 million, increased to 8 million passengers in 1969-70, and further increased to 11.8 million passengers in 1971-72. It was 13.4 million passengers in 2022-23. It is extremely critical for the HSR corridors to ramp up their passengers in the first five to ten years of commercial operation to recover the investment. Paris-Lyon (LGV Sud-Est) of 450 km with 4.4 Cr. passengers in 2019 and about 150 trains a day, both directions may not match Tokaido Shinkansen in terms of profits, but this is another profitable HSR line in the world (Crozet, 2013). Madrid-Barcelona (503 km) route of Spain is the third and is reported to have achieved a ridership of 1.38 Cr. in 2023 and said to have achieved financial viability. Japan, France and Spain developed other HSR corridors from the huge profits that they accrued from their profitable HSR corridors. It was essentially a case of cross-subsidization.

5.5.2 HSR corridors represent all regions, ceteris paribus

India is a vast country with huge aspirations, and the demand for modern and faster transport connectivity like HSR would come from every region. As per Table 7, the main corridor of Delhi-Rewari-Jaipur-Ajmer-Jodhpur-Ahmedabad is ranked first in terms of ridership and connecting national capital with financial capital through western India (Haryana, Rajasthan, Gujarat, and Maharashtra). This corridor could generate huge profits even in this stretch, and when clubbed with the contiguous corridor of Ahmedabad-Mumbai, it may generate windfall profits to fund a couple of HSR projects. However, such a standalone approach to revenue and profit would defeat the very purpose of developing HSR, as it would give the impression that Ahmedabad has been treated preferentially as it is getting connected to both the financial capital and national capital by HSR, when all other regions have no HSR connectivity.

The second main corridor in ranking in terms of ridership is the HSR corridor of Chennai-Mumbai via Tirupati, Bengaluru, Tumkuru, Davangere, Dharwad, Belagavi, Kolhapur, Satara, Pune, and Navi Mumbai. A spur to Goa would also generate huge revenue and profits, which may not be as high as Delhi-Rewari-Jaipur-Ajmer-Jodhpur-Ahmedabad. This represents connecting Mumbai with Chennai via Maharashtra, Goa, Karnataka, Andhra Pradesh, and Tamil Nadu. However, the stretch is very lengthy and hence can be constructed only in phases. The third main corridor in ranking in terms of ridership is the HSR corridor of Delhi, Sonipat, Panipat, Karnal, Ambala, Chandigarh, Ludhiana, Jalandhar, and Amritsar. This connects Delhi with the border of Punjab and passes through Haryana, Chandigarh, UT, and Punjab. The fourth main corridor in ranking in terms of ridership is the HSR corridor of Delhi, Agra, Lucknow, Varanasi, Patna, and Kolkata, which represents the most populous Gangetic plains of UP, Bihar, and West Bengal.

The ruling dispensation promising to initiate feasibility studies for bullet train corridors in North, South, and East India in its election manifesto, means GoI is aware of giving one corridor each for North, South, and East India, as the first HSR between Ahmedabad and Mumbai represents Western India.

5.5.3 Phased development with a scientific approach

The approach in the phased development of HSR should be sensible and cautious. Over 10,000 km of HSR lines must be developed in phases by India, with the corridors that have the best patronage and are therefore more financially viable than the other corridors being considered. It might not be a good idea to rush through the development of numerous corridors at the same time, as it may result in time and cost overruns. The pink book of IR year after year indicates that there were many projects awarded in the Railway budgets prior to 2014 to meet the demands of various political constituencies and shower approvals in their fiefdom with no commensurate availability of funding to execute these projects. In case of HSR projects, the financial closure must be achieved before beginning construction of the project.

In the phased development of HSR corridors, why the highly patronaged corridors should get the priority over the remaining corridors? There are only three HSR lines that are reportedly generated windfall profits for the developers. The first is Osaka-Tokyo (515 km), which saw exponential patronage growth just five years after Shinkansen was introduced. As a result, Japan was able to use the excess revenue from this HSR corridor to develop other HSR corridors, though they were not as financially successful as the Osaka-Tokyo corridor. The second corridor, which is 425 km long and has reportedly reached break-even, is Paris-Lyon and with this excess revenue, TGV expanded its HSR network to different HSR corridors in France and neighbouring countries. The Madrid-Barcelona (503 km) route in Spain is the third and Spanish Railway expanded its HSR network expanded its HSR network to different HSR corridors in Spain and neighbouring countries.

5.5.4 Contiguity of HSR corridors

Some contiguous HSR sections, such as Delhi-Ahmedabad, may have a huge network effect on the Ahmedabad-Mumbai corridor or Mumbai-Pune. Some contiguous HSR sections, such as Varanasi-Patna, may not have a network effect on the Delhi-Agra-Lucknow-Varanasi corridor. Whether each contiguous corridor can bring substantial network effect is to be individually evaluated rather than assuming that all contiguous corridors will bring network effect or will not bring network effect.

5.5.5 Distance of HSR O-D pairs

The O-D pairs, while calculating ridership between 50 km and 1500 km on contiguous corridors, are relevant for pricing and revenue calculations and not beyond 1500 km. The energy expenditure for single-hop air travel, even for 2000 km, may be lower than the energy expenditure of seamless contiguous HSR travel. Taking advantage of a single hop, where the energy spent is huge when lifting the aircraft to 10 km above sea level and then very moderate while travelling till the destination, air fares will be lower than that of HSR fares for distances beyond 1500 km. HSR cannot adopt the telescopic pattern of conventional rail because the energy spent in HSR travel is directly proportional to the distance travelled. The energy spent on rail travel does not increase linearly with speed but non-linearly as the speed increases beyond 200 km. Given this, HSR firms cannot follow the telescopic pattern of fare fixation but will have to go for linearly increasing the fare in proportion to the distance. So, the ridership from contiguous corridors beyond 1500 km cannot be taken for granted. Hence, the economic benefits accruing from such lengthy O-D pairs will also be very limited. However, this will not stop constructing HSR corridors beyond 1500 km as there can be more potential O-D pairs significantly less than 1500 km.

5.5.6 EIRR should not be the criteria for HSR development

The EIRR (Economic Internal Rate of Return) is the one factor that should never be taken into consideration while selecting the best HSR corridors. HSR may have numerous positive externalities, such as Value Capture Financing (VCF) and Transit-Oriented Development (TOD) along the corridor. However, many other positive externalities cannot be converted into financial benefits for the company running the HSR. A railway project can be approved on the EIRR even if it is rejected on the FIRR (Financial Internal Rate of Return). However, that will not be a wise thing to do, as it will lead to the financial bleeding of HSR firms. The financial viability of HSR is the best measure to approve an HSR project.

5.6 HSR corridors to be prioritized during 2025-2035

This report recommends the topmost HSR corridors, as shown in Table 24, of about 2400 km that can be prioritized during 2025-2035 based on the criteria discussed in the previous section.

Table 24 Topmost HSR corridors for 2025-2035

Description	Recommended HSR corridors for 2025-35	Distance (km)	End-to-end passengers 2036-37	
			Daily	Yearly
Main corridor 1	Delhi-Rewari-Jaipur-Ajmer-Jodhpur-Ahmedabad-(Mumbai)*	934	2,09,315	7,63,99,975
Main corridor 2	Chennai-Mumbai via Tirupati, Bengaluru, Tumkuru, Davangere, Dharwad, Belagavi, Kolhapur, Satara, Pune, Navi Mumbai with a spur to Goa	1,366	65,703	2,39,81,595
Main corridor 3	Delhi-Sonipat-Panipat-Karnal-Ambala-Chandigarh-Ludhiana -Jalandhar-Amritsar	665	49,115	1,79,26,975
Main corridor 4	Delhi-Agra-Lucknow-Varanasi-Patna-Kolkata	1,740	31,985	1,16,74,525
	Total	4,705		

Source: Collated from Table 22

The inferences from Table 24 are as follows:

- The four primary corridors listed above will all have ridership levels above the benchmark cited in the HSR literature.
- On the priority list, the Delhi-Rewari-Jaipur-Ajmer-Jodhpur-Ahmedabad (Mumbai) corridor is the first major route. With 79.63 lakh seats between the two cities in 2024,

Delhi-Mumbai is the seventh busiest domestic route in the world and the largest contributor to domestic air traffic in India, covering the two metropolitan cities of Delhi and Mumbai (Patel, 2024, December 20). If this line is adopted, ridership will resemble that of the Tokaido Shinkansen. In 2023, there will be 281,633 end-to-end passengers each day on the Tokaido Shinkansen, whereas in 2036-2037, the Delhi-Mumbai line would have 209,315 passengers. Western India will be represented by this corridor.

- Although the first main corridor between Delhi and Ahmedabad may be implemented simultaneously on two sub-corridors of Delhi-Jaipur and Ahmedabad-Jaipur, if there is any priority, Delhi-Jaipur may be taken up first and then Ahmedabad-Jaipur. Delhi-Jaipur via Gurugram may provide 1.43 Cr. end-to-end passengers on 2036-37 independently. The distance of 270 km is easier and quicker to construct than longer HSR corridors. The air travel and luxury bus travel between Delhi and Jaipur and nearby towns will substantially reduce as the end-to-end travel time between these two cities by HSR will be the least among air, luxury bus, and AC conventional trains. The heavy traffic in the Delhi-Gurugram-Jaipur National Highway will get some relief with the introduction of HSR in this O-D pair. The excess revenue from such a huge ridership in this corridor may be used for developing other HSR corridors. When Jaipur-Ahmedabad is connected by HSR, the number of passengers that travel through Delhi-Jaipur will increase further.
- On the priority list, the Chennai-Mumbai via Tirupati, Bengaluru, Tumkuru, Davangere, Dharwad, Belagavi, Kolhapur, Satara, Pune, Navi Mumbai with a spur to Goa is the second major route. As it is a lengthier route, some sub-corridors should get priority over other sub-corridors in implementation. One of the most appropriate distances for HSR corridor, Chennai-Bengaluru (with a spur to Tirupati from Chittoor) will fetch ridership much more than what a financially viable HSR corridor requires. This would represent Southern India. The route may be extended to Mysuru towards the South and to Kerala at a later point of time. Although Mumbai-Pune is shorter than the minimum distance generally prescribed for HSR corridors, this contiguous corridor will fetch enough ridership and hence this route deserves second priority in the sub corridors of Mumbai-Chennai. This sub corridor will represent central India.
- On the priority list, the Delhi-Sonipat-Panipat-Karnal-Ambala-Chandigarh-Ludhiana-Jalandhar-Amritsar is the third major route. Although lengthier, Delhi-Amritsar corridor will also fetch ridership much more than what a financially viable HSR corridor requires. The excess revenue from such a huge ridership in this corridor may be used for developing other HSR corridors. This would represent the states of Delhi, Haryana and Punjab.
- On the priority list, Delhi-Agra-Lucknow-Varanasi-Patna-Kolkata is the fourth major route. As this is the lengthiest main corridor, this has to be implemented in stages. The sub corridors of Delhi-Agra-Lucknow (442 km), Delhi-Agra-Lucknow-Varanasi HSR via Ayodhya (approximately 890 km) and Delhi-Agra-Lucknow-Varanasi-Patna (1,150 km) along the Gangetic plane of India, will fetch ridership as much as required for a viable HSR corridor. The growth of UP in the decade between 2025 and 2035 will determine whether this corridor will fetch more ridership than what was estimated in the earlier reports.

Although NHSRCL might have prepared the DPR reports for most of these corridors a few years ago, the GoI may have to prepare a fresh DPR, which may give updated figures of ridership, route alignment financial viability and economic benefits.

5.7 Domestic HSR technology for India

It is extremely critical to analyze why India should develop all aspects of High Speed Rail technology indigenously from various angles.

5.7.1 Funding

Funding from HSR countries would be very costly and affect seamless connectivity of contiguous corridors. The expenses associated with building the HSR corridor, which are financed by bilateral agencies, require India to adapt its technology for the section of the corridor that receives financial support from that nation. Currently, thirteen nations - China, Spain, Japan, France, Germany, the United Kingdom, South Korea, Italy, Taiwan, Belgium, the Netherlands, and Luxembourg - have HSR systems in place with a top speed of at least 300 kmph (UIC, 2023, December). If we embrace their technology, there might be other nations outside China that are willing to provide financial support. But there's a catch: Since the Covid outbreak, most of these affluent nations have seen the weakest GDP growth, thus they might not have the resources to support Indian HSR projects (IMF, n.d.). In that case, the financial assistance may not come with loan terms favourable to us.

HSR countries require us to purchase their rolling stock, IT systems, and signal and telecom equipment, which will account for anywhere from 30% to 50% of the whole cost, when they offer financial help for their technology. In addition, they would increase the rates of these imports to make up for the lenient terms on financial aid, which would drive up the cost of building the HSR to an absurd level.

When India wants to be the world's third-biggest economy in a few years, it is not appropriate for India to look to other nations for financial support for the construction of its high-speed rail system. Furthermore, after completing one HSR project, India would be better able to create resources on its own through the formation of an SPV (Special Purpose Vehicle) in which both the central and state governments make major contributions to the project, either from private actors on the VGF model or supported by multilateral organizations like the World Bank and ADB. India may be able to partially overcome the resource allocation problem if it builds HSR progressively over the next 30 years, covering 3000 km every decade. The cost of the construction of HSR in different countries is given in Table 25.

Table 25 Cost of construction of HSR in other countries

HSR Country	Route	Costing Year	Max. design speed (kmph)	Project Cost		Route km	Cost in 2035[c] (INR Cr.)
				INR Cr.[a]	INR Cr./km		
Taiwan	Taipei to Kaohsiung	2007	300	1,06,512	309	345	1,211
Korea	Phase I - Seoul to Daegu	2004	300	80,932	340	238	1,543
China	Beijing-Tianjin	2008	350	21,877	190	115	709
China	Shanghai-Hangzhou	2010	350	37,167	184	202	623
China	Shijiazhuang-Zhengzhou	2012	350	45,635	129	355	396
Spain	Madrid-Barcelona-Figueras	2008	350	1,51,807	203	749	758
France	LGV East	2007	320	64,997	217	300	851
Germany	ICE Frankfurt-Cologne	2002	300	47,401	268	177	1,341
Other European Countries	UIC 2018[b]	2018	200-320	-	118.2 -315	-	496

a Forex conversion has been taken at an average rate of 90 days (Source: xe (n.d.)).

b The cost of construction per km of new HSR line is excluding cost of rolling stock

c The CAGR of cost escalation between 2035 and the year of cost data provided is taken at a rate of 5%

Source: Author's calculations after collating data from various sources

The key inferences that are drawn from Table 25 are as follows:

- The cost of construction per km is the lowest in China even in 2012, as China might have mastered the art of cost reduction by building up HSR of much higher length than other HSR countries. As per World Bank study, the cost of HSR construction in China is one third lower than in other countries (WB, 2014, July 10)
- The latest cost figure of INR 118 - 315 per km of HSR in various European countries indicates it varies depending on the maximum design speed. The more the speed, the more the cost. For instance, the cost of viaduct construction would reduce by 25% if the maximum design speed of viaduct decreases by about 30%.

The construction cost depends on many factors that include land acquisition cost, design speed of HSR, loan terms, technology adopted, purchasing power parity between the donor country and India, exchange rate fluctuations and many other factors. It was estimated in 2015 that the project cost for 500 km Ahmedabad-Mumbai HSR would be INR 1.08 lakh Cr. However, by 2024, the cost was revised to INR 1.65 lakh Cr., which means the CAGR of cost escalation between 2015 and 2024 is 4.82%. As per NHSRCL, the entire project will be completed by the second half of 2028, which means at the same CAGR of cost escalation, the completion cost may be about INR 1.99 lakh Cr. including costs for the initial rolling stock, which is about INR 400 Cr. per km. When rolling stock is to be procured at regular intervals to augment the services, additional costs need to be incurred.

Given this, the HSR enabled countries may estimate the cost of HSR construction in India at least INR 400 Cr./km in 2024 prices. Moreover, India may not get the same favorable financial terms for the next HSR projects as much as it got for the Ahmedabad-Mumbai HSR project from JICA. This may result in huge cash outgo for the repayment of principal and interest rate. In addition to the huge cost of finance, different HSR systems (although all of them may operate on standard gauge) from different countries will not allow the Indian HSR network to operate seamlessly. The HSR network in silos where people must switch from one HSR system to another HSR system cannot bring the synergy inherent in contiguous HSR corridors. The ten coach E5 HSR trainsets are priced at least about INR 460 Cr. (each coach INR 46 Cr.) by Japan. As the negotiation for the price of rolling stock with Japan have not yielded positive results so far, the Ministry of Railways decided to go ahead manufacturing standard gauge HSR two trainsets at a cost of INR 866.87 Cr., each trainset of eight coaches. This cost includes design cost, a one-time development cost, non-recurring charges, a one time cost towards fixtures, tooling and testing facilities, which will be utilised for all future high-speed projects in India (Porecha, 2024, October 15). The idea is not only to develop indigenous capability to design and manufacture HSR rolling stock but also to avoid exorbitant costs of imported HSR rolling stock and HSR system.

The first HSR between Ahmedabad and Mumbai with 81% financial support from Japan has been facing many hurdles as the estimated cost by JICA for this project was INR 1.08 lakh Cr. and the projected cost at the time of completion of the project may be INR 2 lakh Cr. This is essentially due to multiple factors, one among them is the dependency of India on Japan for the supply of about 30% of the various subsystems to be imported from them. For instance, in JICA DPR of 2015, each 10 coach E5 Shinkansen trainset was estimated to cost INR 219 Cr. (at 1 INR = 1.85 JPY) (JICA, 2015, June), whereas in July 2023, Japan demands INR 458 Cr. (at 1 INR = 1.85 JPY) for the same trainset (Dash, 2023, July 06). It is neither financially feasible nor acceptable for India to shell out huge sums of money for the import of the subsystems of HSR pioneer countries. Moreover, the economy of most of the HSR pioneer countries have been far behind than India and it does not augur well for India, which wanted to be a third largest economy. For instance, Japan's GDP CAGR between 1980 and 2024 has been 0.42% (Trading Economics, n.d.e). Given this, it won't be wiser for a faster growing economy like India to depend on HSR pioneer countries either for financial assistance or technology.

In this backdrop, India should consider venturing into developing indigenous technology for HSR, even if the speed of indigenous HSR operation may not be as much as imported technology in the initial years. As per UIC definition, any upgraded conventional line to operate at a maximum speed of 200 kmph and newly constructed line to operate at a maximum speed of 250 kmph is High Speed Rail.

5.7.2 Government equity

There has been a false belief that HSR is a vanity project that exclusively helps the wealthiest 5 percent of people. In some way, this has gathered momentum. This idea will only begin to shift after a HSR is put into service, run, and more individuals from all socioeconomic backgrounds begin using it at least once. It will not be politically right for the government to take the full amount of the fund straight out of its budget. Furthermore, given the priorities for other physical and social infrastructure projects, the governments—both the central government and the individual state governments—cannot afford to devote such substantial sums of money. Therefore, the development of HSR cannot be heavily subsidised by the government of India or the states.

However, the GoI and the respective state governments would have to take token equity to have a say in the project. When the governments change, the budgetary allocation may reduce, resulting in time overrun and cost overrun, making a financially viable project into an unviable project.

In India, except Mumbai Metro Phase 1 and Hyderabad Metro, all other metros have been constructed under the SPV model, where the GoI and the respective state government are the equity holders, GoI provides 20% equity excluding land acquisition and the state government bears land acquisition costs and 20% of the equity of the project excluding land acquisition. The remaining cost of the project excluding land acquisition, which is 60%, has been borrowed from Japan International Cooperative Agency (JICA), a bilateral development organization. Metro projects are sanctioned in phases for shorter distances and hence the equity bearing on the part of GoI and the respective state governments spread over the years and cannot gain the appearance of huge financial burden for the GoI and respective state governments. Although GoI, Government of Gujarat and Government of Maharashtra provided only 10%, 5% and 5% respectively of the total cost of the project, a wrong notion has been created by some section of the society that this project involves enormous public expenditure and debt financing, which should have been used for social infrastructure and poverty eradication (The Hindu, 2017, October 6 and Raghu, 2014, June 08).

In the case of the first HSR project between Ahmedabad and Mumbai, although JICA committed only 80% of the project cost in the beginning, it may offer more than 90% of the project cost for the same now with the revised expenditure, as Japan owned up the project. The burden on the GoI, Government of Gujarat and Government of Maharashtra is only 5%, 2.5%, and 2.5% of the total cost of the project, respectively. This may not happen anymore for any future HSR projects as the HSR pioneer countries have not been in good shape financially. Moreover, when India becomes third largest economy, it is expected that it supports its HSR project with its finances or utmost from multilateral agencies like WB and ADB.

5.7.3 Payment method

It is next to impossible to award the construction of HSR on PPP as there is hardly any appetite for such a long-term project from private players. Even if the government resorts to the Hybrid Annuity Model where the government may give about 40% of the total construction cost and the private player brings about 60% from both equity and debt to encourage private participation along with revenue sharing, the investment to be made by the government will be huge.

5.7.4 Funding from multilateral agencies

It has been estimated that the cost of 500 km first HSR project between Ahmedabad and Mumbai may cost INR 2 lakh Cr. by the time it is finished in 2028. Due to learning curve, if it is assumed that the same cost of INR 400 Cr. per km, to develop 2000 km of HSR between 2025 and 35, at least INR 8 lakh Cr. is required in ten years by the time project is completed. The central and the respective state governments contributions may be to the tune of 20% of the project cost and not beyond that, as much as they have contributed to the first HSR project. Given this, the other option for the government is to seek funding from multilateral agencies and bilateral agencies.

However, there is a restriction on seeking funds from multilateral and bilateral agencies. The total multilateral and bilateral resource envelope for India on a per-annum basis is about USD 10 billion - USD 15 billion for all purposes in 2019. In terms of INR and the conversion rate of INR 80/USD, it would be INR 80,000 Cr. to INR 1,20,000 Cr. This was fixed based on the GDP of India. With growth in GDP, the limit will go increase along with the need for developmental projects on various fronts. If India could borrow to the tune of INR 1,20,000 Cr. per year between 2025 and 2035, it would amount to INR 12 lakh Cr. This is for all project requirements and not just for HSR projects alone, whereas HSR projects may require 6.4 lakh Cr. (80% of the total project cost).

5.8 Indigenous development of HSR system in India

Over the past few decades, IR has made improvements to its signal and telecom systems, rolling stock development, traction systems, and civil engineering construction technology, all of which are reasonably on par with the technological advancements occurring in their respective domains. However, IR has not developed any cutting-edge technology that has fundamentally changed the way it operates. Therefore, it is essential to comprehend how the nations who invented HSR systems created their technology, procedures, HSR policy, operations, and traffic management from the scratch before attempting to determine how India should build HSR technology on its own.

5.8.1 Learnings from other countries in brief

There are about six countries which pioneered the development of HSR from scratch since 1964 till 1992. Although many other countries adopted HSR and constructed HSR aggressively like China, they cannot be termed as "pioneer" in HSR. This section reviews and encapsulated the learnings from the six pioneer countries.

5.8.1.1 Japan (1964)

Japan was the first country to develop HSR on its own. The current maximum design speed of 350 kmph and the current maximum operating speed of 320 kmph have evolved over three decades. Japan developed the first faster train called the "3000 series SE Romancecar" in 1957 for narrow gauge with a maximum speed of 145 kmph, which was the maximum speed of rail transport at that point in time (Tokyo Railway Labyrinth, 2022). When the first Shinkansen trains, the 0 series, were introduced on October 1, 1964, the maximum speed was 210 kmph and then later increased to 220 kmph. With improved rolling stock, Japan increased its maximum speed to 230 kmph, 270 kmph, and 300 kmph on the Tokaido Shinkansen, and this speed enhancement journey spanned between 1957 and 1997 (Mochizuki, 2011). The same approach was followed by other routes of the Shinkansen. Japan has been developing many new trainsets to operate on existing and new Shinkansen routes at speeds up to 320 kmph. The E5 train set, which can go at a maximum speed of 320 kmph, is the one that will be supplied for the Ahmedabad-Mumbai HSR corridor.

The development of HSR in Japan offers numerous lessons. First, they invented the HSR technology entirely on their own and never borrowed it. Like how suburban trains in Mumbai took advantage of the linear landscape of Mumbai Island, Japan saw an opportunity to build a common carrier mode by utilizing the country's linear landscape. Shinkansen has covered 2664 km on 15 O-D pairs since it began service. Other than this, 378 km and 583 km have been planned, and under construction, respectively. Their needs for the development of HSR have nearly reached saturation. Their enthusiasm for creating HSR hasn't faded, though (International HSR System Summary: JAPAN, n.d.). Japan aims to reach the same milestone in Maglev even though they are leaders in Wheel-on-Rail HSR. The Maglev (Chou Shinkansen) alignment has been gradually built, first between Tokyo and Nagoya (286 km) via a new alignment that passes through an inland country. Although numerous test-runs at a maximum speed of 603 kmph on Maglev have been conducted, the original completion date of 2027 has been extended to 2032 (CNN, 2016, October 19 and Jiji, 2024). It is anticipated that the Nagoya-Osaka would be finished by 2047. Japan has basically been working on this to stimulate their economy because the reduction in travel time will increase the productivity and efficiency of their people.

Apart from creating Chou Shinkansen, Japan kept enhancing Shinkansen train sets, resulting in a decrease in energy usage. When the trains were running at 220 kmph, for example, Series 100 trains used just 79% of Series 0, Series 300 trains used only 73% of Series 0, Series 700 trains used only 66% of Series 0, and Series N700 trains used only

51% of Series 0. When operating at 270 kmph, one of the newest series N700s used 61 units of energy, as opposed to 91 units for the Series 300 and 84 units for the Series 700 (Briginshaw, 2014).

They market their technology not just through technology transfer but also through generous financial support after seeing that there is hardly any need for further high-speed rail to be created on a war footing in Japan. To help India establish its first high-speed rail project, for which it lacked the necessary financial resources and technology, Japan offered to lend 81% of the project's construction costs, with a 50-year payback period, a 15-year moratorium, and an interest rate of 0.1% annually.

Japan decided to establish HSR on standard gauge, despite the country's traditional train lines being narrow gauge. Instead of creating HSR on a narrow gauge to enable interoperability between the conventional rail and HSR systems, they chose not to do so. By carefully examining their circumstances and arriving at their own conclusions, they created HSR on standard gauge, while retaining the conventional rail on narrow gauge. The primary goal of Japan's HSR development is to close the enormous supply-demand imbalance that resulted from Japan's focus to develop economy aggressively since the dilapidation of Japan due to World War II. The standard gauge with wide bodied coaches has been able to carry more passengers per coach compared to its counterpart in narrow gauge.

In order to bring standard-gauge coaches' carrying capacity up to line with that of broad-gauge coaches, they also constructed wide-bodied coaches for standard-gauge Shinkansen. Even though Shinkansen and traditional narrow-gauge lines intersect at stations, they follow separate, dedicated routes, which prevents the speed differential that could have otherwise occurred and lowered Shinkansen's throughput.

5.8.1.2 Italy (1977 & 1988)

After Japan, Italy was the first European country to introduce HSR (called Direttissima) for 122 km of the total distance of 238 km between Rome and Florence in 1977 at a maximum speed of 250 kmph, and subsequently 52 km, 20 km, and 44 km, respectively, in 1985, 1986, and 1992, respectively. Italy also runs some routes at 220 kmph and 300 kmph.

Italy is the first country to experiment with the development and deployment of tilting trains called "Pendolinos" for achieving high speeds. It was able to achieve 35% more speed on conventional tracks compared to normal trains, which ran at a maximum speed of 160 kmph and a maximum speed of 250 kmph on HSR tracks (TRB, 1979).

Italy also charted its own path in developing its HSR, either by upgrading the conventional rail line with tilted trains or HSR on dedicated tracks. It did not develop all HSR corridors uniformly at the same maximum speed and developed HSR corridors at varying maximum speeds based on local conditions and demand (International HSR System Summary: ITALY, n.d.)

5.8.1.3 France (1981)

France developed and commercially operated its HSR in 1981 between Paris and Sud-Est at a maximum speed of 260 kmph, then increased its speed to 300 kmph (Bouley, 1994). Unlike Japan, where HSR is in standard gauge and conventional rail is in narrow gauge, France developed HSR in a "mixed HSR" mode, whereby HSR would operate on conventional lines once it reaches the suburbs of the city so that the existing conventional rail connectivity is utilized by HSR trains, thereby eliminating the need to develop new alignment for HSR in the suburban areas, which are exceptionally costly. This was possible because both the conventional rail and HSR are of standard gauge in France. This is the precise reason why the SNCF-RITES-Italfer Consortium, in its pre-feasibility study on HSR between Ahmedabad, Mumbai, and Pune, recommended a broad gauge for HSR with a "mixed HSR" model. This would allow the HSR trains to travel beyond the dedicated tracks of HSR, such as Ahmedabad-Mehsana and Mumbai-Nashik. France also operates HSR at a speed of 300 kmph and 320 kmph on various routes, depending on the scope and demand (International HSR System Summary: FRANCE, n.d.).

5.8.1.4 Germany ICE (1988)

There are three unique features of the German HSR. The first one is that since the 1970s, German federal transportation has upgraded its conventional railway lines with an incremental approach up to 200 kmph on several segments. In addition to this, HSR lines on exclusive new alignments were also built to provide a maximum speed of up to 300 kmph (Global Railway Review, 2021).

The second is that HSR was implemented in numerous short and medium-distance segments by Germany. Passenger flow has been measured since 1991, when the ICE 1 was introduced between Hannover and Fulda (248 km) between 1991 and 1994 in stages at a maximum speed of 280 kmph. This is even though the first HSR line was opened in 1988 between Fulda and Würzburg (90 km) with a maximum speed of 280 kmph. Even though HSR has been running in Germany between ten distinct O-D pairs—some of which are adjacent—the network's overall length has been 1285 km, indicating that an average O-D pair is roughly 128.5 km (International HSR System Summary: GERMANY, n.d.). Germany has been flexible in adding new HSR corridors at varied speeds, depending on the needs and area. Among the ten corridors that were in use, the following were operated at different speeds: 280 kmph for Fulda-Würzburg, Hannover-Fulda, and Mannheim-Stuttgart; 250 kmph for Hannover (Wolfsburg)-Berlin and Köln-Düren; 300 kmph for Köln-Frankfurt and Nürnberg-Ingolstadt; and 230 kmp for Hamburg-Berlin. Among the three HSR corridors that are under development, München-Augsburg, (Leipzig/Halle) Gröbers, and Nürnberg-Erfurt will operate at a maximum speed of 230 kmph, 300 kmph, and 250 kmph, respectively (International HSR System Summary: GERMANY, n.d.).

The third is that Germany is currently concentrating on creating and offering HSR services to neighbouring towns within Germany and in other European nations, including Frankfurt, Brussels, London, Frankfurt, Amsterdam, Berlin, Warsaw, and Frankfurt-Paris, as a follow-up to the development of HSR within Germany (International HSR System Summary: GERMANY, n.d.).

5.8.1.5 Austria (1990)

Austria developed its HSR on upgraded conventional tracks and new HSR lines by operating three routes at a maximum speed of 200 kmph, one route at a maximum speed of 220 kmph, and three routes at a maximum speed of 230 kmph. Austria developed HSR between Vienna, Linz, and Salzburg (300 km) and in the lower Inn valley between Wörgl and Innsbruck (65 km), which are designed for 250 km/h and operated at up to 230 km/h. Traffic demand has doubled between Vienna and Linz, with positive effects beyond this line since it has been operating at high speed. The "OBB RailJet" high-speed trains, unlike HSR trainsets, have been operating in push-pull fashion and connect Austria with Germany, Switzerland, Hungary, the Czech Republic, and Italy (Global Railway Review, 2017). The benefit of locomotive-hauling HSR trains is that the coaches will be available in case the locomotive fails or requires maintenance. The rigid coupling between the wagons allows the train to have wider, pressure-tight gangway connections. OBB Railjet combines the characteristics of multiple units with those of normal locomotive-hauled trains. Moreover, the trainset can be shortened or extended by individual wagons and adapted to traffic volumes on individual routes in a better way. In cases of high passenger volumes, the train sets can be connected in tandem.

The Austrian HSR is unique in that all the energy needed to run it is derived from renewable sources. The largest distance between any two distant cities is about 500 km in Austria. The most important takeaway from the Austrian HSR model is that they only intended for the maximum speed of 200 to 230 kmph because they had restricted demands when designing their system. As a result, they did not aim for higher HSR speeds, which may have required much more work in terms of resources and time. High-speed travel has been made possible by the maximum speed of 200 to 230 kmph, even when they need to connect to other nations (Global Railway Review, 2017).

5.8.1.6 Spain (1992)

The learning on HSR would be incomplete without the magnificent efforts of Spain in developing HSR through various technological innovation measures. Spain is unique and special in developing HSR for various reasons. Spain has the largest HSR network of 3966 km in the world, second only to China. In addition to this, 5000 km of HSR network is also planned in Spain (Nunno, 2018). Spain developed its first HSR between Madrid and Seville on a standard gauge of 1.435 m (which is also called international gauge or UIC gauge). Although its conventional railway operates on an Iberian gauge of 1.668 m, Spain has been able to achieve "mixed HSR" as the trains are equipped to alter their wheelset gauge from one gauge to the other while being on the run with the support of a third rail (Railway Technology, 2001). However, the trains that run on dedicated HSR tracks use the standard gauge alone, whereas the trains that switch from standard gauge to Iberian gauge and vice versa have been able to extend HSR services to 50 additional cities (International HSR System Summary: SPAIN n.d.).

Spain HSR also uses the rolling stock of French Alstom and Bombardier TGV, Siemens Velaro ICE of Germany, CAF, and Talgo of Spain on its HSR network, which is thereby flexible enough to connect with other HSR systems. Despite the technical complexities of tilting trains, locomotive-agnostic train sets, and gauge conversion while the train is on the run, the on-time performance has been about 99% (International HSR System Summary: SPAIN n.d.).

Administrador de Infraestructuras Ferroviarias, or Administrator of Railway Infrastructures (Adif), oversees infrastructure management and capacity allocation. Renfe-Operadora operates three types of services. The first one is AVE (Alta Velocidad Espanola, or "Spanish highspeed"). These long-distance services (such as Madrid-Lleida at 519 km and Madrid-Valencia/Albacete at 432 km, among others) operate on dedicated standard-gauge HSR tracks at a maximum speed of 300 kmph without any subsidy from the government. The second one is Alvia. These long-distance services operate on both standard gauge and Iberian gauge tracks, with a maximum speed of up to 250 kmph on high-speed lines and up to 220 kmph (135 mph) on conventional lines. The third one is Avant, a medium-distance service for short journeys with a maximum speed of 250 kmph and an average speed of about 150 kmph. Spain operates different models for various distances at different speeds depending on the availability of high-speed dedicated tracks, its tilting trains, and demand. The key lesson from the Spanish model is that one size does not fit all and there is nothing wrong in adopting different technologies to achieve different speeds for different O-D pairs (International HSR System Summary: SPAIN n.d.).

5.9 NHSRTC for indigenous development of HSR

An R&D centre designated for the development of different HSR models and speed augmentation in India, with the name of "National High Speed Rail Technology Corporation" (NHSRTC), should be established by the GoI. Prominent academic establishments like IITs, IISCs, and NITs; research organisations; startups; and foreign companies that could be willing to assist in developing certain design elements could be enlisted to support and expedite NHSRTC's research and development.

HSR is defined by UIC as "The rail transport on new tracks with a maximum operating speed of at least 250 kmph and on upgraded tracks with a maximum operating speed of at least 200 kmph'. Many countries have attempted both simultaneously and achieved success on both fronts. The recently released tender of "Technical, Commercial, Legal, Financial, etc., study and drafting the bid document for demonstrative project on Hyperloop/any other emerging" of IR demands that the selected consultant should evaluate various High Speed Transportation systems that include High Speed Rail, Maglev and Hyperloop, among other things Emerging Transportation Technology (Railway Board, 2024). However, IR needs to create demonstrative project of indigenous HSR, indigenous Maglev and indigenous Hyperloop exclusively to take a lead among the world nations in high speed transportation system.

One of the key components of ADB project of TA IND 57027-001 Decarbonizing Transport in India by Increasing Modal Share of Railways in Passenger and Freight Traffic is to look into the potential of these five corridors for developing semi-high-speed corridors and assess the modal shift from air and road to rail between important cities post-introduction of semi-high-speed corridors and estimate FIRR and EIRR for each of these corridors. As per the ToR of this ADB project, the track is not fit to accommodate train speeds of 160 km per hour and higher, which the Vande Bharat train sets are capable of, and how to make the conventional rail routes operate VB trains at their maximum speed and the investment required for the same (ADB, 2024). Given this, there are at least four tasks that may be assigned to the NHSRTC with reference to the technological development of HSR systems in India.

5.9.1 Demonstrative new HSR system at 250 kmph

Rather than attempting to construct an indigenous HSR system to reach the maximum design speed of 350/320 kmph, India could start its demonstration project with a 100 km stretch of a workable HSR route, with a target speed of 250 kmph. In roughly five years, a demonstrative project on the HSR system for a 100-kilometer stretch on one of the routes between Chennai and Bengaluru, Delhi and Jaipur, or Delhi and Chandigarh might be developed at a maximum speed of 250 kmph. All throughout the HSR pioneer countries, the increase in maximum operating speed has been gradual. The Ministry of Railways awarded a contract to BEML to design and develop HSR train sets that can run at a maximum design speed of 280 kmph (The Hindu Bureau, 2024, October 16). The indigenously designed VB trainset can run at a maximum speed of 180 kmph and aiming 280 kmph in the very first attempt, that too within 2026, may not be practically feasible.

It is not about developing one dimension of the HSR such as rolling stock but developing all that constitutes HSR system, which includes civil design, station design and development, rolling stock, traction equipment, power supply, signal and telecommunication, integrated centralized control and maintenance yards for rolling stock so that all of them work seamlessly with each other

5.9.2 Demonstrative upgraded HSR system at 200 kmph

The 180 kmph maximum operating speed of VB trains and the physical infrastructure's readiness to handle such a high speed clearly do not match. If the conventional tracks can support maximum speed of 200 kmph, the VB trains may be operated at 180 kmph as the civil design speed has always been higher than the rolling stock maximum speed. Therefore, creating a technological framework and carrying out a demonstration project on an existing line of roughly 100 km may be NHSRTC's second job to reach a maximum speed of at least 200 kmph in the conventional lines.

By creating a project that serves as an example, the relevant railway zones would be able to implement the necessary technology to build important routes that can reach a top speed of 200 kmph. Except for suburban areas, most of the Mumbai-Ahmedabad conventional line has been upgraded to a maximum speed of 160 kmph from 130/100 kmph in around three years. It is feasible for NHSRTC to create a demonstration project for 100 km with a 200 kmph top speed in five years.

Mission Raftaar was to enhance the speed of HDN1 and HDN3 to a maximum speed of 160 kmph. Instead of incrementally upgrading from 130/100 kmph to 160 kmph in these two corridors, it is better to leapfrog and achieve a maximum speed of 200 kmph, thereby developing "upgraded HSR" status in these two corridors.

5.9.3 Tilted HSR trains at a speed of 200 kmph

For three reasons at least, it is extremely difficult for IR to modify its current conventional rails to allow general trains to reach a top speed of 200 kmph smoothly over all sections. It is nearly impossible to modify the telecom, OHE signal, track equipment, alignment to permit 200 kmph on fully operational IR tracks. Such changes can also include additional land acquisition, incurring high upgrade expenses, or possibly moving the stations. IR may need several decades to update the traditional tracks to support the maximum speed of 200 kmph, considering the IR route length of about 69000 km.

Talgo coaches, which are essentially tilting coaches, ran on Indian tracks in 2016 with Indian locomotives between Delhi and Mumbai in 11 hours and 42 minutes, reaching a maximum speed of 150 kmph, whereas Rajdhani Express has been taking 15 hours and 50 minutes at a maximum speed of 130 kmph. This was achieved after a successful increase in the maximum speed of Talgo coaches in this stretch. Talgo coaches also ran an 84-km stretch between Mathura and Palwal in 38 minutes flat, clocking a speed of 180 kmph, breaking the record set by the Gatimaan Express (Jacob, 2016).

VB trains, on trial runs, reached the maximum speed of 180 kmph on specific sections, whereas Talgo trains on the existing tracks without any upgrade could reach 150 kmph. Otherwise, the maximum permitted speed for VB trains is 130 kmph/100 km on Indian Railways.

The third task for NHSRTC is to develop tilting trains in cooperation with countries where such a kind of tilting technology is available. The question of importing such tilting trains is ruled out as Spain has been demanding more than twice the cost of VB trains for each Talgo train with the same capacity as that of VB trains, although Talgo claims that the maintenance costs of Talgo coaches are much lower than those of VB trains. Moreover, IR requires a larger number of tilting trains (both sleeper version and seating version) to meet the extensive network and huge demand for faster travel.

5.9.4 Radially aligning self-steering bogies for freight trains

At present, IR operates four types of trains (freight trains, ordinary trains, express/mail trains, and premium trains) with different average speeds, resulting in differentials in speed and hence affecting the throughput. With the development of tilting trains, the maximum speed of passenger trains that use tilting coaches may increase significantly. But the issue of speed differentials will persist even then, as there will be at least four types of train services on the IR network: freight trains with a maximum speed of 70 kmph, ICF technology coaches with a maximum speed of 100 kmph, till they continue in the services or are retrofitted with LHB coupling, LHB coaches with a maximum speed of 130/160 kmph, and tilting trains at a maximum speed of 200 km. Even if the ICF technology trains are outpaced over a period, there will still be three types of trains with different maximum speeds. The wider the maximum speeds, the lower the throughput. Once the IR network is used for a maximum speed of 200 kmph, the maximum speed of freight trains is also to be substantially increased. This is possible only with developing radially aligning self-steering bogies for freight trains, and hence the task of developing radially aligning self-steering bogies for freight trains should be on the agenda of IR. If IR could cater only to two speeds, one speed of 130/160kmph for LHB passenger services and 130 kmph for radially aligning self-steering bogies for freight trains and the second speed of 200 kmph with tilting trains for passenger services, the throughput of the IR would essentially improve.

South Africa developed and has been using radially aligned self-steering Scheffel bogies for transporting iron ore from Sishen to Saldanha Port for 861 km with a gross trailing load of 41,760 tonnes and a payload of 34,800 tonnes, whereas India's Super Vasuki, the longest freight train with six locos and 295 wagons, in its trial run, carried a total trailing load of about 27,000 tonnes of coal. Besides the Scheffel bogies increase the wheel life up to 500%, the rail life on curves up to 25 times and shunting stability up to 100%. The Scheffel bogies reduce wagon maintenance up to 70%, fuel consumption by 5% and flange-related derailments up to 100%. (Bradfield and Fröhling, 2013).

The fourth task for NHSRTC should be the task of developing radially aligning self-steering bogies for freight trains on par with Scheffel bogies, which could reach a higher capacity and speed in about five years. Although Scheffel bogies were tested for a maximum speed of 200 kmph for a short distance of 10 km on Cape gauge of 1067 mm, the commercial speed has been much lower due to multiple factors of number of locomotives and wagon attached.

The EDFC and WDFC have been designed to achieve a maximum speed of 100 kmph and an average speed of about 70 kmph. The development of DFCs in India has been tardy, and even if IR decides to develop 10,000 km of DFC in the future, it may take many decades. Instead of relying on new DFC projects that would increase the capacity to transport more freight, IR should think of utilizing existing conventional lines and already developed EDFC and WDFC corridors more effectively.

Indian Railways needs a comprehensive solution, which goes beyond simply building new HSR at higher speed. All train speeds along the existing lines need to be significantly and concurrently increased. While the introduction of VB trains has improved passenger amenities, speed, and stability, stand-alone methods for creating some semi-high-speed train sets might not increase IR’s throughput overall.

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