No.

MINISTRY OF RAILWAYS,
GOVERNMENT OF INDIA

THE FEASIBILITY STUDY ON THE DEVELOPMENT OF DEDICATED FREIGHT CORRIDOR FOR DELHI-MUMBAI AND LUDHIANA-SONNAGAR IN INDIA

FINAL REPORT

Volume 2
TASK 0&1

OCTOBER 2007

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.
JAPAN RAILWAY TECHNICAL SERVICE
PACIFIC CONSULTANTS INTERNATIONAL

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Exchange Rates

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INR1.00 = JPY 2.77

PREFACE

At the Japan-India Summit Meeting in Delhi on the 29th of April 2005, eight-fold initiative for strengthening Japan-India Global Partnership was agreed by the Prime Ministers of both countries. Japan and Indian governments share the view that Japan's Special Terms for Economic Partnership (hereinafter referred to as "STEP") Scheme could be one of the effective means for carrying out large scale priority projects in infrastructure sector in India and confirmed their intention to examine the feasibility of the project, providing the inputs of Japanese technology and expertise.

In July 2005, The Government of India (hereinafter referred to as "GOI") officially requested the Government of Japan (hereinafter referred to as "GOJ") for Japan's technical cooperation to assist in the feasibility assessment of a high priority transport development initiative, the "Dedicated Multimodal High-axle Load Freight Corridors with Computerized Train Control System on Mumbai-Delhi and Delhi-Howrah" (hereafter referred to as the Project).

In response to the request from the GOI, Japan International Cooperation Agency (hereinafter referred to as "JICA") dispatched in October 2005 a contact mission to collect and analyze the necessary information for the above mentioned Project. JICA and the Ministry of Railways (hereinafter referred to as "MOR") agreed that the feasibility study of the Project would be executed jointly. Based on the result of the preliminary study, the GOJ decided in November 2005 to conduct the feasibility study on the development of a multimodal high axle load freight corridor with computerised control for Delhi-Mumbai and Delhi-Howrah (hereinafter referred to as "the Study").

In February 2006, JICA dispatched the preparatory study team, and the Scope of Work of the Study and the Minutes of Meeting were signed and exchanged between MOR and JICA.

In May 2006, JICA selected and dispatched the Study Team headed by Mr. Minoru Shibuya of Nippon Koei Co., Ltd., and consisting of Nippon Koei Company Limited, Japan Railway Technical Service, and Pacific Consultants International.

This report compiles the results of the Study that was carried out between May 2006 to the end of October 2007 and covers deliberation of various aspects of the Project such as the engineering feasibility, financial viability, and environmental and social consideration; all aspects being the key issues essential for the feasibility of the Project. Throughout the implementation of the Study, an Advisory Committee chaired by Mr. Katsuji Iwasa, Senior Advisor of Japan Freight Railway Company Limited, was organised to assist and to advise JICA and the Study Team for the execution of the study, as well as to coordinate and adjust the various stakeholders on the Japanese side. I would like to convey my appreciation to Mr. Iwasa and the members of the Advisory Committee for their continuous support to us.

Finally, it is my hope that this report will contribute to the realization of the Project and I wish to express my sincere appreciation to the officers of the Ministry of Railways of the Government of India who have devoted their time, provided information, and cooperating in good spirit with the Study Team for the completion of the Study.

October 2007

Eiji Hashimoto
Vice-President
Japan International Cooperation Agency

October 2007

Mr. Eiji Hashimoto

Vice-President

Japan International Cooperation Agency

Letter of Transmittal

Dear Sir,

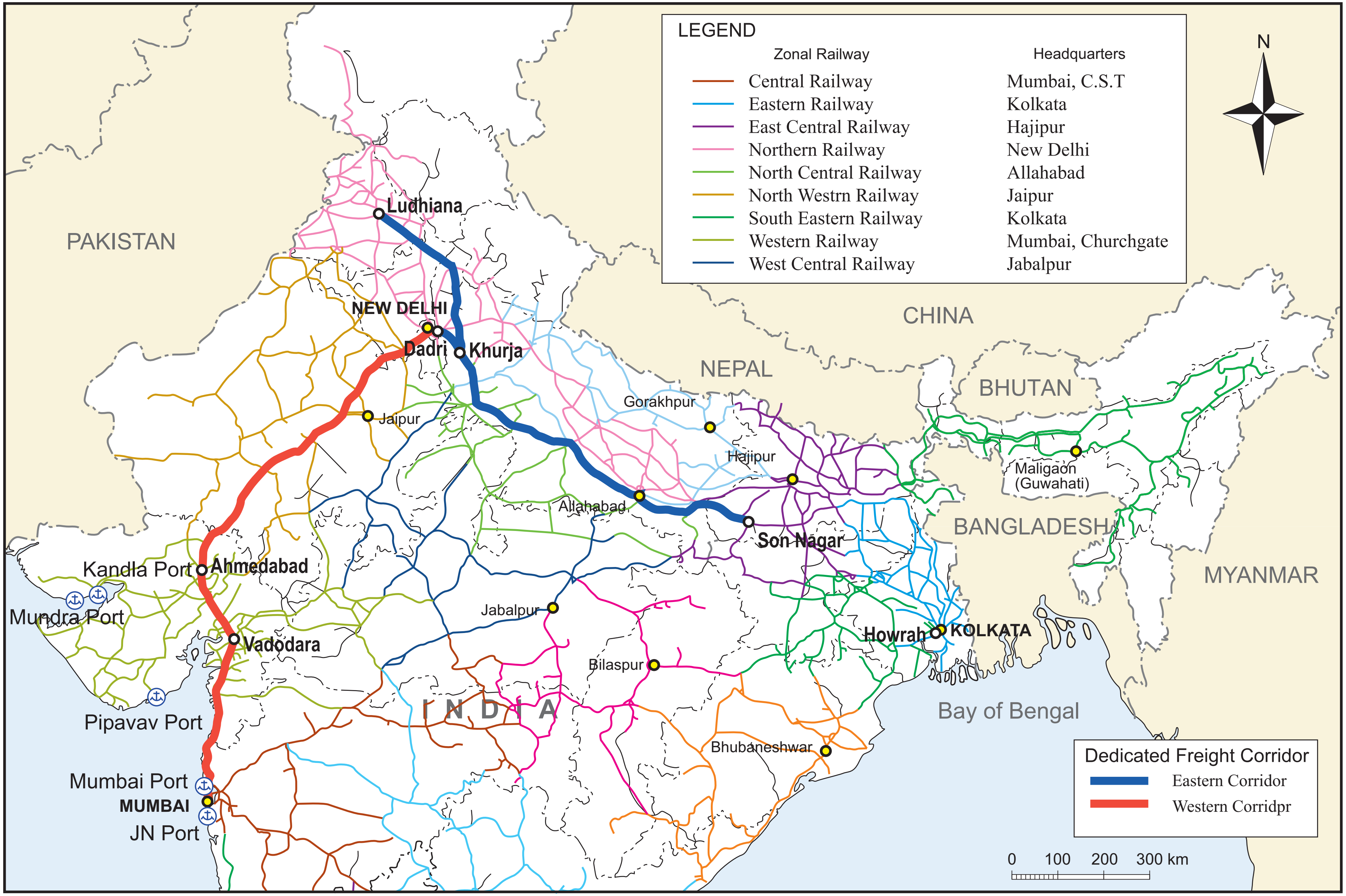
We have the pleasure of submitting herewith the Final Report on the "Feasibility Study on the Development of Dedicated Freight Corridor Delhi-Mumbai and Ludhiana-Sonnagar in India" (hereinafter referred to as the Study.).

The Study was undertaken from May 2006 to the end of October 2007 by the Study Team. The Study Team headed by Mr. Minoru Shibuya of Nippon Koei Co., Ltd., and is consisted of Nippon Koei Co., Ltd., Japan Railway Technical Service, and Pacific Consultants International.

We would like to express our sincere gratitude and appreciation to all the officials of your agency and the JICA Advisory Committee, the Ministry of Foreign Affairs, the Embassy of Japan in India, the Ministry of Railways as the counterpart agency, and to all of the counterpart personnel.

Yours faithfully,

Minoru Shibuya
Team Leader
Feasibility Study on the Development of
Dedicated Freight Corridor for Delhi-Mumbai and
Ludhiana-Sonnagar in India



LOCATION MAP

PROJECT AT A GLANCE

Project at a Glance (Entire Project)

No.	Description	Details	
		Western Corridor	Eastern Corridor
0	**Alignment**		
		JNPT - Vasai Rd – Vadodara – Ahmedabad – Ajmer – Rewari - Dadri	Sonnagar - Mughal Sarai – Kanpur – Khurja - Dadri, and Khurja – Kalanaur - Dhandari Kalan
1	**Route length**		
	Total Length - Double line - Single line	1,468 km 1,468 km -	1,309 km 883 km 426 km
2	**Gradient**		
	- Ruling gradient	1 in 200 (5/1000)	
	- Steepest gradient in yards	1 in 1200 (0.83/1000) 1 in 400 (2.5/1000) exceptional case	
3	**Standards of construction**		
	- Gauge	1,676 mm	
	- Rails	60 kg/m UIC/90 UTS rail, HH rail	
	- Sleepers	PSC 1660 nos./km density for main line, 1540 nos./km density for loop line & sidings	
	- Points & crossings	60 kg rails, 1 in 12 with curved switches and CMS crossings on PSC fan shaped sleepers or FFU (Fibre reinforced Formed Urethane) sleepers Minor loop lines and non-running lines,1 in 8 1/2 turnout	
	- Ballast	300 mm cushion	
	- Maximum speed	100 km/hr	
	- Type of traffic and axle load	Double stack container movement on well type wagon and 5800 tonne train hauling with 25 tonne axle load	
4	**Formation (Detour Route)**		
	- Bank width for double line	12.5 m	
	- Slope of embankment	2H: 1V	
	- Cutting width for double line	14.9 m (11.9 m+1.5 m extra for each side for side drains)	
	- Slope of cutting	1:1	
	- Blanketing	0.60 m depth	

No.	Description	Details	
		Western Corridor	Eastern Corridor
5	**Curves**		
	- Maximum degree of curvature	2.5 degree curve (700 m radius)	
	- Curve compensation	At the rate of 0.04 % per degree of curvature	
6	**Moving dimensions**		
	- Vertical MMD	6.83 m for DSC	
7	**Vertical SOD**		
		7.76 m for DSC	
8	**Track centres**		
	Between two tracks of DFC	5.5 m	
	Between existing track and DFC	6.0 m	
9	**Bridges**		
	- Standard of loading	30 tonne axle load, 12 tonne/m trailing load	
	- Total linear water way of important bridges	12,810m (18 bridges)	2,660m (6 Bridges)
	- Total linear water way of major bridges	16,890 m	9,740m
10	**Road crossings**		
	- Total nos. of road under bridges (New on Detour)	133	79
	- Total nos. of Automatic Railway Crossing	505	368
	- Total nos. of road over bridges (Replacing)	27	8
	- Total nos. of road under bridges (Existing)	357	202
11	**Rail flyover**		
	- Total Nos of rail flyover	41	31
12	**Stations**		
	- Junction stations	9 stations	12 stations
	- Terminal stations	3 stations	2 station (Not Including Dadri)
	- Crossing stations Double line Single line	 32 stations -	 16 stations 36 stations

No.	Description	Details	
		Western Corridor	Eastern Corridor
13	**Tunnel**		
	- Number of tunnels	1	0
	- Total length of tunnel	4,000m	-
14	**Land required**		
	- Track	5,411 ha	2,832ha
	- ROBs	44 ha	12 ha
	Total	5,455 ha	2,844 ha
15	**Detour Route**		
	- Total length of Detour Route	474 km	275 km
16	**Signalling and Telecommunication System**		
	- Type of signalling	Automatic signalling using AF track circuit with advanced TPWS	
	- Section length on double line	1.5 km between stations 1 km nearby station	
	- Telecommunication System	GSM-R system	
17	**Train Traction System**		
	- Type of Train	Electric	Electric
	- Electrification system	25 kV AC	
	- Type of feeding system	AT feeding system (25kVx2)	
18	**Project Cost (mil. Rs)**		
	- Construction Cost	164,655	110,540
	- Consulting Service Cost	5,432	3,419
	- Physical Contingency	10,079	7,356
	- Price Escalation	18,838	13,749
	- Land Acquisition	26,640	25,495
	- Taxes	2,234	1,326
	- General Administration Cost	10,599	7,235
	- Interest during Construction	9,608	7,102
	- Procurement of locomotive	39,334	36,217
	Total Cost	**287,420**	**212,437**

No.	Description	Details	
		Western Corridor	Eastern Corridor
19	**Train operation**		
	- Operation Type	One manned operation without brake van	
	- Maximum speed	100 km/hr	
	- Traffic capacity Double line Single line	 140 nos. per day direction (4 hours maintenance block) 25 nos. per day direction(4 hours maintenance block)	
	- Train length	Corresponding to 686 m CSR	
20	**Economic and financial analysis**		
	- EIRR	14.09 %	15.26 %
	- FIRR	9.08 %	15.59 %
21	**Evaluation of induced impact**		
	- Induced impact on production	1,386 billion Rs.	
	- Induced impact on gross value added (GVA)	700 billion Rs.	
	- Induced impact on tax revenue	22 billion Rs.	
	- Induced impact on operating surplus	249 billion Rs.	
	- Induced impact on household income	372 billion Rs.	
	- Induced impact on employment	1.1 million people	

Project at a Glance (Phase I-a)

No.	Description	Details	
		Western Corridor	Eastern Corridor
0	**Alignment**		
		Vadodara – Ahmedabad – Ajmer - Rewari	Mughal Sarai - Kanpur - Khurja
1	**Route length**		
	- Total Length	918 km	710 km
2	**Gradient**		
	- Ruling gradient	1 in 200 (5/1000)	
	- Steepest gradient in yards	1 in 1200 (0.83/1000) 1 in 400 (2.5/1000) exceptional case	
3	**Standards of construction**		
	- Gauge	1,676 mm	
	- Rails	60 kg/m UIC/90 UTS rail, HH rail	
	- Sleepers	PSC 1660 nos./km density for main line, 1540 nos./km density for loop line & sidings	
	- Points & crossings	60 kg rails, 1 in 12 with curved switches and CMS crossings on PSC fan shaped sleepers or FFU (Fibre reinforced Formed Urethane) sleepers Minor loop lines and non-running lines, 1 in 8 1/2 turnout	
	- Ballast	300 mm cushion	
	- Maximum speed	100 km/h	
	- Type of traffic and axle load	Double stack container movement on well type wagon and 5800 tonne train hauling with 25 tonne axle load	
4	**Formation (Detour Route)**		
	- Bank width for double line	12.5 m	
	- Slope of embankment	2H: 1V	
	- Cutting width for double line	14.9 m (11.9 m+1.5 m extra for each side for side drains)	
	- Slope of cutting	1:1	
	- Blanketing	0.60 m depth	

No.	Description	Details	
		Western Corridor	Eastern Corridor
5	**Curves**		
	- Maximum degree of curvature	2.5 degree curve (700 m radius)	
	- Curve compensation	At the rate of 0.04 % per degree of curvature	
6	**Moving dimensions**		
	- Vertical MMD	6.83 m for DSC	
7	**Vertical SOD**		
		7.76 m for DSC	
8	**Track centres**		
	Between two tracks of DFC	5.5 m	
	Between existing track and DFC	6.0 m	
9	**Bridges**		
	- Standard of loading	30 tonne axle load, 12 tonne/m trailing load	
	- Total linear water way of important bridges	5,970m (4 bridges)	1,620m (2 Bridges)
	- Total linear water way of major bridges	7,960m	2,200m
10	**Road crossings**		
	- Total nos. of road under bridges (New)	87	48
	- Total nos. of Automatic Railway Crossing	317	212
	- Total nos. of road over bridges (rebuilt	1	2
	- Total nos. of road under bridges (extension)	207	110
11	**Rail flyover**		
	- Total Nos of rail flyover	29	18
12	**Stations**		
	- Crossing stations Double line	21 stations	14 stations
	- Junction stations	7 stations	8 stations
	- Terminal stations	0 stations	0 stations

No.	Description	Details	
		Western Corridor	Eastern Corridor
13	**Tunnel**		
	- Number of tunnels	0	0
14	**Land required**		
	- Track	3,329 ha	1,683ha
	- ROBs	2 ha	6 ha
	Total	3,331 ha	1,689 ha
15	**Detour Route**		
	- Total length of Detour Route	292 km	153 km
16	**Signalling System**		
	- Type of signalling	Automatic signalling using AF track circuit with advanced TPWS	
	- Section length on double line	1.5 km between stations 1 km nearby station	
	- Telecommunication System	GSM-R system	
17	**Train Traction System**		
	- Type of Train	Electric	Electric
	- Electrification system	25 kV AC	
	- Type of feeding system	AT feeding system (25kVx2)	
18	**Project Cost (mil. Rs)**		
	- Construction Cost	93,464	61,355
	- Consulting Service Cost	3,393	1,376
	- Physical Contingency	6,770	4,913
	-Price Escalation	12,653	9,182
	- Land Acquisition	16,339	15,143
	- Taxes	1,332	540
	- General Administration Cost	6,628	4,202
	- Interest during Construction	6,222	4,597
	- Procurement of locomotive	39,334	36,217
	Total Cost	**186,136**	**137,526**

No.	Description	Details	
		Western Corridor	Eastern Corridor
19	**Train operation**		
	- Operation Type	One manned operation without brake van	
	- Maximum speed	100 km/h	
	- Traffic capacity Double line Single line	 140 nos. per day direction (4 hours maintenance block) 25 nos. per day direction(4 hours maintenance block)	
	- Train length	Corresponding to 686 m CRS	

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A	AAR	Association of American Rairoads
	ABB	Air Blast Breaker
	ABS	Absolute Blocking System
	AC	Super high voltage transmission
	ACD	Anti-Collision Device
	ADB	Asian Development Bank
	ADI	Ahmedabad Division
	ADV	Advisior
	AF	Audio Frequency
	AFTC	Audio Frequency Track Circuit
	AGA	Agra
	AGC	Agra Division
	AII	Ajimer Division
	ALD	Allahabad Division
	AM	Additional Member
	AOH	Additional Overhaul
	AP	Andhra Pradesh
	APSEB	Andhra Pradesh State Electricity Board
	ARE	Automatic Air Brake System
	ARTC	Australian Rail Track Corporation
	ASN	Asansol Division
	AT	Auto-transformer
	ATC	Automatic Train Control
	ATO	Automatic Train Operation
	ATP	Automatic Train Protection
	ATS	Automatic Train Stop
	ATSP	Automatic Train Stop Control with Speed Pattern Profile
	AUG	Aurangabad
	AWR	Alwar
	AxC	Adoption of Axle Counter
B	BCCL	Bharat Coking Coal Limited
	BCLA	Container Wagons with Automatic Couplers
	BCLB	Container Wagons with Fixed Coupler
	BESCOM	Bangalore Electric Supply Company
	BG	Broad Gauge
	BHEL	Bharat Heavy Electrical Limited
	BKI	Bandikui
	BMA	Bangalore Metropolitan Area
	BMP	Bangalore Mahangara Palika (Bangalore City Government)
	BMRTL	Bangalore Mass Rapid Transit Limited
	BNW	Bhiwani

	BPAC	Block Proving by Axle Counter
	BPK	Billion Passenger Km
	BRD	Baroda
	BRDA	Bangalore Regional Development Authority
	BSC	Base Station Controllers
	BSS	Base Station System
	BT	Booster Transformer, Boosting Transformer
	BTKM	Billion Tonne Km
	BTS	Base Transceiver Station
	BVH	Ballabgarh
	BWSSB	Bangalore Water Supply and Sewerage Board
C	CAD	Computer Aided Dispatch
	CAGR	Compound Annual Growth Rate
	CAPEX	Capital Expenditure
	CARG	Compound Annual Rate of Growth
	CAS	Collision Avoidance System
	CCEA	Cabinet Committee of Economic Affairs
	CCGT	Combined Cycle Gas Turbine
	CCH	Chinchwad
	CCI	Chamber of Commerce and Industry
	CCL	Central Coalfields Limited
	CDM	Clean Development Mechanism
	CDMA	Code Division Multiple Access
	CEA	Central Electric Authority
	CERC	Central Electricity Regulatory Commission
	CFA	Cash Flow Projection
	CFS	Container Freight Station
	CL	Curve Length
	CLS	Colour Light Signal
	CLW	Chittaranjan Locomotive Works
	CM	Construction Management
	CMA	Chennai Metropolitan Administration
	CMDA	Chennai Metropolitan Development Authority
	CMR	Construction Manager
	CMS	Cast Manganese Steel
	CMWSSB	Chennai Metropolitan Water Supply and Sewerage Board
	CNB	Kanpur
	CNG	Compressed Natural Gas
	CNOC	Consolidated National Operations Center
	CO2	Carbon Dioxide
	CONCOR	Container Corporation of India Ltd.
	CPT	Chennai Port Trust
	CR	Central Railway
	Cr.	Crore

	CRCS	Computerized Route Control System
	CRIS	Centre for Railway Information Systems
	CS	Crossing Station
	CSO	Central Statistics Organization
	CSR	Clear Standing Room
	CTC	Centralized Traffic Control System
	CTCC	Centralized Traffic Control Centre
	CWSS	Cauvery Water Supply Scheme
D	DB	Design & Build
	DBB/ DBD	Design-Bid-Build
	DBOM	Design-Build-Operate-Maintain
	DCT	Double Coupled Train
	DDR/ DER	Dadri
	DEC	Delhi Cantt
	DFC	Dedicated Freight Corridor
	DFCCIL	DFC Corporation of India Ltd.
	DGPS	Differential GPS
	DH	Diamond Harbor
	DHN	Dhanbad
	DL/ DLI	Delhi
	DLW	Diesel Locomotive Works
	DMRC	Delhi Metro Rail Corporation
	DMRTS	Delhi Mass Rapid Transport System
	DO	Dausa
	DPC	Dedicated Passenger Corridor
	DR	Detailed Railway Noise and Vibration Survey
	DRB	Detailed Railway Noise and Vibration Survey at Bridge
	DRP	Detailed Railway Noise and Vibration Survey at Plain Route
	DSC	Double-stack container
	DSS	Double Slip Switch
	DT	Double Track
	DTMF	Dual Tone Multi Frequency
	DUA	Distant Urban Area
E	ECL	Eastern Coalfields Limited
	ECR	East Central Railway
	EDI	Electric Data Interchange
	EGNOS	European Geostationary Navigation Overlay Service
	EIA	Environmental Impact System
	EIRENE	European Integrated Railway Radio Enhanced Network
	EIRR	Economic Internal Rate of Return
	EJR	East Japan Railway
	ELI	Existing Line Improvement
	ELL	Electric Leveling Luffing
	EMaP	Environmental Management Plan

	EMC	Electromagnetic Compatibility
	EMoP	Environmental Monitoring Plan
	ER	Eastern Railway
	ERTMS	European Rail Traffic Management System
	ES	Engineering Services
	ESA	European Space Agency
	ESCS	Environment and Social Consideration Study
	ESIMMS	Environmental and Social Impact Mitigation Measures Study
	ETCS	European Train Control System
	ETSI	European Telecommunication Standards Institute
	EU	European Union
	EUDL	Equivalent Uniformly Distributed Load
	EWG	Environmental Working Group
F	F/S	Feasibility Study
	FCL	Full Container Load
	FDI	Foreign Direct Investment
	FDMA	Frequency Division Multiple Access
	FIRR	Financial Internal Rate of Return
	FL	Formation Level
	FLP	Freight Logistic Park
	FLS	Final Location Survey
	FO	Freight Operations
	FOIS	Freight Operations Information System
	FS	Feasibility Study
	FSW	Friction Stir Welding
G	G.Noida	Greater Noida
	GADEROS	Galileo Demonstrator for Railway Operation System
	GAIL	Gas Authority of India Limited
	GAR	Guntur
	GBAS	Ground-based Augmentation System
	GC	General Consultants
	GDP	Gross Domestic Product
	GGC	Gangapur City
	GHz	Giga Harzs
	GIS	Geographic Information System
	GL	Ground Level
	GNSS	Global Navigation Satellite Systems
	GOI	Government of India
	GOJ	Government of Japan
	GOM	Government of Maharashtra
	GPRS	General Packet Radio Service
	GPS	Global Positioning System
	GQ	Golden Quadrilateral
	GSDP	Gross State Domestic Product

	GSDP	Gross State Domestic Product
	GSDPi(y)	GSDP of state in the year
	GSM	Global System for Mobile communication
	GSM-R	Global System for Mobile Communication for railway applications
	GT	Gas Turbine
	GTI	Gateway Terminal India
	GTO	Gate Turn Off Thrystor
	GU	Gujarat
	GZB	Ghaziabad
H	H.P.	Himachal Pradesh
	ha	Hectare
	HH	Head Hardened
	HLR	Home Location Register
	HO	Head Office
	Hp	Horse Power
	HPGCL	Haryana Power Generation Co. Ltd.
	HSR	Hisar
	HT	High Tension
	HWH	Howrah
	HYC	Hydrabad
	Hz/	Hertz
I	IA	Intersection Angle
	IBS	Intermediate Blocking System
	IC	Independent Consultant
	IC	Inspection C
	IC	Radio Frequency Identity
	ICCP	Information and Community Consultation Programme
	ICD	Inland Container Depot
	ID	Identification
	IE	Independent Engineer
	IEC	Ineternational Electrotechnical Commission
	IEE	Initial Environmental Examination
	IGBT	Insulated Gate Bipolar Transistor
	IGM	Import General Manifest
	IMO	Independent Monitoring Organization
	IOH	Intermediate Overhaul
	IP	Intersection Point
	IPCC	Intergovernmental Panel on Climate Change
	IPGCL	Indraprastha Power Generation Co. Ltd.
	IR	Indian Railways
	IRR	Internal Rate of Return
	IRR	Inner Ring Road
	ISO	International Organization for Standardization
	ISO	International Organization for Standardization

	IWT	Inland Water Transport
J	J Yen	Japanese Yen
	J&K	Jammu and Kashmir
	J.N. Port	Jawaharlal Nehru Port
	JAI	Jaipur
	JARTS	Japan Railway Technical Service
	JBIC	Japan Bank for International Cooperation
	JETRO	Japan External Trade Organisation
	JICA	Japan International Cooperation Agency
	JN	Junction
	JNPCT	Jawaharlal Nehru Port Container Terminal
	JNR	Japanese National Railways
	JOD	Jodhpur
	JR	Japan Railway
	JS	Junction Station
	JST	JICA Study Team
	JV	Joint Venture
K	KBI	Knorr-Bremse India
	KBPS	Kilo Bites Per Second
	KDS	Kolkata Dock System
	KEB	Karnataka Electricity Board
	KoPT	Kolkata Port Trust
	KPCL	Karnataka Power Corporation Limited
	KPR	Kanpur
	KPTCL	Karnataka Power Transmission Corporation Limited
	KRCL	Konkan Railway Corporation Ltd
	KUIDFC	Karnataka Urban Infrastructure Development & Finance Corporation
	KUWS&DB	Karnataka Urban Water Supply and Drainage Board
L	LCL	Less than Container Load
	LCX	Leaky Coaxial Cable
	Leq	Equivalent noise level
	LNG	Liquefied natural Gas
	lpcd	Litre per capita per day
	LT	Low Tension
	LUD	Ludhiana
	LWR	Long Welded Rail
M	M	Million
	M.P.	Madhya Pradesh
	MAL	Malanpur
	MARS	Multi Access Reservation System
	MCL	Mahanadi Coalfields Limited
	MDB	Moradabad
	MDP	Mandideep
	MEPZ	Madras Export Processing Zone

	MGD	Million Gallon per Day
	mld	million litre per day
	MLIT	Ministry of Land Infrastructure and Transport, Japan
	MM	Man Months
	MMD	Maximum Moving Dimensions
	MMRDA	Mumbai Metropolitan Regional Development Authority
	MMU	Mobile Maintenance Units
	MOEF	Ministry of Environment and Forest
	MOF	Ministry of Finance
	MOR	Ministry of Railway
	MOR road	Manali Oil Refinery Road (Chennai)
	MORD	Ministry of Rural Devevelopment
	MOU	Memorandum of Understanding
	MPs/MLAs	Member of Paliament/Member of Legislative Assembly
	MRTS	Mass Rapid Transit System
	MRVC	Mumbai Rail Vikas Corporation Ltd.
	MSC	Mobile Switching Center
	mtpa	Million tons per annum
	MTR	Mid-term Rehabilitation
	MTRC	Mobile Train Radio Communication
	MU	Million Unit (=1,000,000kWh)
	MUL	Mulund
	MUTP	Mumbai Urban Transport Project
	MUX	Multiplexer
N	NAG	Nagpur
	NATM	New Austrian Tunnelling Method
	NCL	Northern Coalfield Limited
	NCR	National Capital Region
	NDE	New Delhi
	NDP	Net Domestic Product
	NEEPCO	North Eastern Electric Power Corporation
	NER	North Eastern Region
	NESDP	National Economic and Social Development Plan
	NGO	Non-Governmental Organization
	NH	National Highway
	NHAI	National Highways Authority of India
	NHDP	National Highways Development Project
	NHPC	National Hydro Power Corporation Limited
	NMDP	National Maritime Development Programme
	NMPT	New Mangalore Port Trust
	NR	Northern Railway
	NRP	National Rehabilitation Plan
	NRVY	National Rail Vikas Yojana
	NRVY	National Rail Vikas Yojana

	NSDP	Net State Domestic Product
	NSICT	Nhava Sheva International Container Terminal
	NTKM	net tonne km
	NTPC	National Thermal Power Corporation
	NTPC	National Thermal Power Plant Co. Ltd.
	NWR	North Western Railway
O	OFC	Optical fiber cable
	ONGC	Oil and Natural Gas Corporation Ltd.
P	PAF	Project Affected Family
	PAP	Project Affected People
	PB	Performance Bond
	PCM	Pulse Code Modulation
	PESB	Public Enterprise Selecting Board
	PETS	Preliminary Engineering cum Traffic Study
	PIT	Pitampur
	pkm	Passenger Kilometer
	PLF	Power Load Factor
	POH	Periodical Overhaul
	POL	Petroleum-Oil-Liquid
	PPP	Public Private Partnership
	PPTA	Project Preparatory Technical Assistance
	PPTA	Project Preparatory Technical Assistance
	PSC	Prestressed Concrete
	PSEB	Punjab State Electricity Board
	PSU	Public Sector Undertaking
	PWD	Public Works Department
R	R&M	Renovation and Modernization
	RAP	Resettlement Action Plan
	RC	Reinforced Concrete
	RDSO	Research Designs and Standards Organization
	REW	Rewari
	RITES	Rail India Technical and Economic Services
	RL	Rail Level
	RLMS	Rural Load Management System
	RMG	Railed Mounted Gantry Crane
	ROB	Road Over Bridge
	ROBs	Road Over Bridges
	ROH	Routine Overhaul
	ROW	Right-of-Way
	RRD	Ravtha Road
	RRP	Framework of Resettlement and Rehabilitation Plan
	RRR	Reinforced Rail Road
	RS	Railway Station
	Rs.	Indian Rupees

	RTK	Real Time Kinematics
	RTRI	Railway Technical Research Institute
	RUB	Road Under Bridge
	RVNL	Rail Vikas Nigam Limited.
	RWF	Railway Wheel Factory
S	SBAS	Satellite-based Augmentation System
	SBI	Sanarmati
	SC	Schedule Castes
	SCADA	Supervisory Control And Data Acquisition
	SDH	Synchronous Digital Hierarchy
	SEBs	State Electricity Boards
	SECL	South East Central Coalfield Limited
	SERCs	States Electricity Regulatory Commission
	SEZ	Special Economic Zone
	SGC	State Grievance Committee
	SGSN	Serving GPRS Support Node
	SH	State Highways
	SIPCOT	State Industries Promotion Corporation of Tamil Nadu Ltd.
	SMTP	Sub-Manifest Transshipment Permit
	SOD	Schedule of Dimensions
	SP	Section Post
	SPAD	Signal Passed at Danger
	SPART	Self-propelled Accident Relief Trains
	SPCM/ID-PAF	Stakeholder/Public Consultation Meeting and Identification of PAFS
	SPURT	Self Propelled Ultrasonic Rail Testing
	SPV	Special Purpose Vehicle
	SR	Sensitive Receptor
	SRSF	Special Railway Safety Fund
	SRTUs	State Road Transport Undertakings
	SSC	Single Stacked Container
	SSI	Solid State Interlocking
	SSS	Single Slip Switch
	ST	Schedule Tribes
	sta.	Station
	STEP	Special Terms for Economic Partnership
	STM	Synchronous Transfer Mode
	Stn	Station
	SVN	Space Vehicle Number
T	TA	Technical Assistance
	TAC	Track Access Charge
	TCI	Transport Corporation of India
	TCL	Transitional Curve Length
	TERI	The Energy and Resources Institute
	TETRA	Terrestrial Trunked Radio

	TEU	Twenty feet equivalent unit
	TKD	Tughlakabad
	tkm	Track Kilometer
	TLD	Track Loading Density
	TMCP	Thermo-Mechanical Control Process
	TMG	Tire Mounted Gantry Crane
	TNEB	Tamil Nadu Electricity Board
	TNRDC	Tamil Nadu Road Development Corporation
	TOR	Terms of Reference
	tpa	Tons per annum
	TPP	Thiruvottiyur Ponneri Panchetti
	TPWS	Train Protection and Warning System
	TS	Terminal Station
	TSS	Traction Substation
	TU	Transport Units (tkm+pkm)
	TVU	Train Vehicle Unit
	TWS	Thick Web Switches
	TWS&DB	Tamil Nadu Water Supply and Drainage Board
U	U.P.	Uttar Pradesh
	UFW	Unaccounted for water
	UIC	Union Internationale Chemins de Fer
	ULBs	Urban Local Bodies
	UP	Unit Price
	UPRVUNL	Uttar Pradesh Rajya Vidyut Utpadan Nigam Ltd.
	UrEDAS	Urgent Earthquake Detection and Alarm System
	UTS	Ultimate Tensile Strength
V	VCB	Vacuum Circuit Breaker
	VCL	Vertical Curve Length
	VK	Vakkadu
	VRRC	Village Resettlement and Rehabilitation Committee
	V-SAT	Very Small Aperture Terminal
	VTMS	Vessel Traffic Management System
W	WB	World Bank
	WCL	Western Coalfield Limited
	WCR	West Central Railway
	WDM	Wave Division Muyltiplexing
	WLC	With line capacity
	WOL	without the maintenance interval
	WR	Western Railway

CHAPTER 1
INTRODUCTION

CHAPTER 1 INTRODUCTION

Corridors which connect major urban centers of Mumbai, Delhi, Kolkata and Chennai are called as "Golden Quadrilateral". The corridors are placed as the most important and indispensable corridors for economic growth of India. Railway transport has been playing an important role along the corridors in the land transport market. However, now, the task of drastic expansion of railway transport capacity in India has become the most important and urgent, because the existing railway transport system can not catch up with the increased demand which has been derived from recent rapid economic growth of India. Direction to attain the task was discussed at the Japan-India Summit Meeting in Delhi in April 2005, and "the two sides shared the view that Japan's Special Terms for Economic Partnership (STEP) Scheme could be one of the effective means for carrying out large-scale priority projects in infrastructure sector in India. The two sides confirmed their intention to examine the feasibility of proposals for dedicated multimodal high-axle load freight corridors with computerized train control system on Mumbai-Delhi and Delhi-Howrah routes utilizing STEP Scheme and with the inputs of Japanese technology and expertise". In July 2005, Government of India (hereinafter referred to as "GOI") officially requested Government of Japan (hereinafter referred to as "GOJ") for the execution of Japan's technical cooperation to assess the feasibility on the development of dedicated multimodal high-axle load freight corridors with computerized control for Delhi-Mumbai and Delhi-Howrah in India (hereinafter referred to as "The Project").

In response to the request from the GOI, in October 2005, Japan International Cooperation Agency (hereinafter referred to as "JICA") dispatched the contact mission to collect and analyze necessary information for the Project. Based on the result of the preliminary study, in November 2005, GOJ decided to conduct "the feasibility study on the development of multimodal high axle load freight corridor with computerized control for Delhi-Mumbai and Delhi-Howrah" (hereinafter referred to as "the Study"). In February 2006, JICA dispatched preparatory study team, and the Scope of Work of the Study and the Minutes of Meeting were signed and exchanged between MOR and JICA.

In June 2006, JICA dispatched the Study Team to India for the Study for commencement of the site survey. Study area of the Study is as below, which is confirmed in S/W between the GOJ and GOI.

1) DFC Western Corridor: Jawaharlal Nehru Port Terminal (JNPT) - Dadri, Tuglakabad ICD including branch lines

2) DFC Eastern Corridor: Sonnagar – Dhandarikalan (Ludhiana), Khurja – Dadri including branch lines

The GOI decided to extend the DFC Eastern Corridor from Sonnagar to a planned deep seaport in Kolkata area. MOR and the Study Team had a series of discussion to include the extended section into the Study. However, the section was excluded from the Study, since location of the deep seaport in the Kolkata area was not decided within the Study period.

The Study consists of the following 3 tasks.

1) Task 0 : Base-line Survey for Railway Transport Capacity Development
2) Task 1: Justification of the Construction of the New Freight Corridor
3) Task 2: Feasibility Study on the Dedicated Freight Corridor Project

The Study Team has finished all the tasks mentioned above and compiled the results as the Final Report. This report provides all results of Task 0 and 1 among the above three Tasks.

The Final Report not only integrates the following reports which were submitted to GOI in the past but also reflects valuable comments on the report made by concerned personnel.

Jun. 2006 Inception Report	: Explanation of policies of the Study
Sep. 2006 Progress Report 1	: All items of the Task 0 with Study policies on Task 1
Dec. 2006 Interim Report 1	: All items of the Task 0 with parts of Task 1
Mar. 2007 Progress Report 2	: All items of the Task 0 and 1 with Study policies on Task 2
Jul. 2007 Interim Report 2	: All items of the Task 0 and 1 with parts of Task 2
Sep. 2007 Draft Final Report	: All Study results of Task 0, 1 and 2

The Study reviewed the feasibility study on DFC development between Delhi – Mumbai and Delhi – Howrah, i.e. "Preliminary Engineering-cum-Traffic Study (PETS)", conducted by Indian side (by RITES Ltd.). In addition to this, the Study complemented important items which international financing organizations needs for their project evaluation when financial assistance is requested. These items shown below are lacking in the RITES report.

i) Evaluation of feasibility of the DFC as an optimum alternative (Task 1)

ii) Comparison of major technology options concerned to DFC

iii) Social and environmental consideration study

iv) Study on organization/institution and financial plan of DFC

v) Study on Intermodal transport and facilities

vi) Comprehensive evaluation of the Project

It is needless to say that items from i) to iv) and vi) are generally necessary to apply financial assistance request to international financing organizations. The v) is an item which should be duly studied in this Project in particular. It should be emphasized that the new freight railway line contributes to only a part, though it is the most important, of the whole corridor transport system. In other words, the new freight railway line only is not able to complete the necessary freight transport service by itself. Intermodal services to supplement the railway service, such as developments of ports, inland container depot (ICD), access road railway feeder lines, are absolutely indispensable. This means the DFC investment would not be effective enough, if the proper intermodal service is not developed simultaneously.

The Study Team made a detailed study and proposed necessary conditions to synchronize the DFC development on the provision of intermodal facilities and services putting stress on the Western Corridor, where the intermodal function of the new railway service would be critical.

As mentioned before, this report shows the Task 0 and 1 study results. The Feasibility study results on the new freight railway (Task 2) is compiled in Volume 3.

The following is the list of volumes consisting the Final Report, which covers all the Study results.

Volume 1 : Executive Summary

Volume 2 : Main Report (Task 0 & 1)

Volume 3 : Main Report (Task 2)

Volume 4 : Annex 1 Technical Working Papers

Volume 5 : Annex 2 Preliminary Design Drawings

Furthermore, this Final Report was prepared based on the comments received on October 17th 2007 from the Ministry of Railways (MOR) on the Draft Final Report that was submitted to the MOR on September 18th 2007.

Finally, it should be mentioned that a report entitled "Study on Development of Intermodal Freight Transport Strategy – Final Report -", JICA, March 2007, which was studied and submitted by the Intermodal Research Unit of the Study Team, and that studies on intermodal development and project evaluation in this report are completed by utilizing the results of the above report.

CHAPTER 2
CURRENT CONDITION AND ISSUES
PERTAINING TO THE TRANPOSRT SECTOR SCENARIO IN INDIA

CHAPTER 2 CURRENT CONDITION AND ISSUES PERTAINING TO THE TRANSPORT SECTOR SCENARIO IN INDIA

2.1 INTRODUCTION

This section clarifies the current condition for the entire transport network in India, including the present position of railways in that network and the issues that will be faced by them in the future.

To investigate this, a summary of the current scenario of Indian Railways is presented and then viewed from the standpoint of national transport plans, such as the 10th 5-Year Plan, and the results of various other studies and investigations that have been presented till now. After that, the role of road, air and rail in domestic transport will be viewed in terms of passenger and freight transport sectors. And then Indian Railways will be compared with railroads in other countries with large land masses to reinforce its gigantic scale. Then the conditions found in the various types of transport sectors in the region along the DFC will be presented.

This chapter will show the reciprocal relationship of these transportation sectors and the perceived changes in the role of Railways. The following is a summary of the conclusions in this section.

(1) Issues and Directions in Transport Sector of India

To further transport infrastructure development: Delay in development of transport infrastructure is a serious obstruction to the economic growth in India. It is necessary to make extensive investments in transport infrastructure.

To establish a cost efficient system for long distance transport: Delhi and its surrounding areas are located far from seaports. It is necessary to reduce transport cost for the long distance transport in order to promote foreign trade.

To improve quality of service: The quality of service is still low even though freight rates and passenger fares are low. It is necessary to improve the quality of transport services in order to satisfy the ever-increasing demand by providing higher quality services.

To balance economic viability and social needs: Poverty alleviation, balanced regional development, and other social restructures are important issues of India. It is necessary to provide adequate transport means for poor people and to develop rural road networks.

To control environmental load: With increasing income level, India increases energy consumption and vehicle emissions, and this trend will continue. It is necessary to formulate an environmental friendly transport system.

(2) Issues and Directions in Freight Distribution System of India

To improve efficiency of inter-modal facilities: Unending time spending at inter-modal terminals such as transhipment facilities in seaports and ICDs cause time and money losses. It is necessary to reduce time spending and to speed up handling at inter-modal facilities.

To simplify procedures of freight transport: It is necessary to reduce time and money spending for export and import, checkpoint procedures, and other freight transport procedures.

To improve road network around inter-modal facilities: Congestion around inter-modal terminals is very heavy and causes delays in freight transport. It is necessary to reduce the traffic congestion.

To encourage inter-modal transport: In order to save economic cost of freight transport and to reduce environmental load, it is necessary to promote an inter-modal transport concept in the sector.

To modernize vehicle fleets and freight transport facilities: It is necessary to modernise truck terminals and warehouses, and to introduce 3-axle rigid trucks and tractor- trailer trucks instead of 2-axle rigid trucks, identify relevant trucks, and other modern trucks for efficient on-land freight transport.

To reform freight industry: Trucking industry in India is not necessarily reliable. Most of the operators are classified into unorganised sector, and are suffering low profit in high competitive market. On the other hand, freight container transport by rail is monopolised by CONCOR with high freight rates. It is necessary to encourage adequate competitive market and reliable enterprises in the Indian freight transport market.

(3) Role of Railways in the transport sector in India

- Indian Railways, which were built much before improvement of roadways, form a vast domestic network within India. The railway is a core transportation organization in this vast country.

- While share held by the railway has declined in recent years due to improvements in roadways, the role that the railway is playing in the current dramatic economic growth remains large and the traffic volume for both passenger and freight sectors continues to grow year after year.

- Usage of shipment is so limited in India continental land that the role of railway being eco-friendly, having large volume capacity needs to be quite high.

- As the safety and punctuality of railway transport is better than that of road transport, increase of the share of railway transportation is expected to enlarge.

- On a railway that is newly constructed or improved, large capacity and high speed can be provided. Modernization of equipment of sidings at ports, mines and factories will result in effective and economical transport. It is expected to contribute significantly to the expansion of Indian economy.

(4) Issues to be addressed by Indian Railways

- The increase in the number of trains corresponding to the increasing demand has nearly reached to its limit of transport capacity under the current infrastructure. Indian Railways must remove these barriers to grow, so that it can proactively respond to this demand and take on the increase in freight and passenger transport demand.

- A comparison of the freight rates in India with those in other countries shows that they are exceptionally high. There is a need to find out a fare structure that meets the railway transport cost and yet is in range with the fares of other modes of transport.

- The concept of setting train schedules is being established when the traffic volume corresponds to one trainload between origin and destination for both passenger and freight trains. In future, there will be need to operate trains with attention to the need of the users, such as user-friendly train operation.

- Freight transport compatible with modern manufacturing systems need to be able to provide information about when the freight will arrive at their destination.

- The management of railway is required to provide proper service according to the requirement of the market, though there are difficulties in improving the operating system of the railways.

- Railway is required to be not only the public transport means for common use and social development, but also a financially balanced transport service organ with efficient operation.

2.2 SUMMARY OF RAIL TRANSPORT IN INDIA AND THE NATIONAL TRANSPORT IMPROVEMENT PLAN

2.2.1 Summary of Track System of the Indian Railways

With some 62,000 km of tracks, Indian Railways has one of the largest rail networks in the world. This network is a mixture of broad gauge, meter gauge and narrow gauge lines due to the differences in application and the entity that had been in charge of the construction. Some 75% of the network is broad gauge (1.676m) and there is an ongoing effort to standardize the other sections to broad gauge.

Among the main trunk lines that form the “Golden Quadrilateral", which links the four major metropolitan cities, some of them are being converted into double-track electrified lines. This includes the sections between Delhi and Mumbai, Delhi and Kolkata and Delhi and Chennai. The line toward the south from Mumbai remains a single-track, non-electrified route.

Some 24% of the entire route is electrified. However, as of 2005, there is a total of 10 million horsepower by diesel locomotives being used in comparison to 13 million horsepower by electric locomotives, showing that the traffic capacity by electric operation has already been growing. There are even a few steam locomotives remaining.

The railway is under the jurisdiction of the Ministry of Railways. The entire railway system has been divided into 16 zonal railways that are controlled by the Railway Board of the Railway Ministry in Delhi. As of June 2005, this rail system employed 1.47 million people.

The *2002 Status Paper* stated that there are 473 million tons of freight and 4,833 million passengers transported annually. This results in 233 billion rupees of freight revenue and 105 billion rupees in passenger revenue. Key expenditures include 188 billion rupees for personnel, 108 billion for fuel and 30 billion for leasing fees.

Most of the freight transported is bulk items, of which 89% of the volume transported comes from coal, fertilizer, cement, limestone, grain, iron and iron ore. However, towards the end of the twentieth century other forms of transportation, such as overland trucking, pipelines and domestic ocean freight, took over some of the transport commodities such as cement, fertilizer and iron. This has been reason of declining railway share.

Some 60% of all passengers come from the four main cities of Delhi, Kolkata, Chennai and Mumbai. 27% of these are long-distance passengers. However, in terms of passenger kilometers, passenger transport in urban regions does even reach 20%. And the passenger income for this 20% comes from the fares charged to the first class traveling passengers, which is less than 1% of the total passengers.

While accidents are on the decline, on an average there are some 20 collisions and 300 derailments per year along with several cases of on board train fires. This causes deaths of dozens of passengers.

2.2.2 The Rail Improvement Plan in the National Improvement Plan

According to "India's Transport Sector, 2002" by the World Bank Report, the current situation of India's transport sector is as follows. Twenty-five percent of national and state highways are congested. Truck and bus speeds averages only 30-40 km per hour. All high- density rail corridors face severe capacity constraints. In Mumbai and other metropolitan cities, overcrowding during peak hours is common in commuter trains and buses." "In India, the major economic centers are not linked by expressways. Most national highways are two-lane or less; only 3,000 km are four-lane." "Poor transport services impact the Indian economy —and Indian society in general—in a number of direct and indirect ways. An enormous amount of time, and therefore money, is wasted because of the inefficient movement of people and goods."

The tenth five-year plan targets a sustainable annual economic growth in the 8% range, but the insufficient economic infrastructure for roads, railways and other forms of transport is hampering the attainment of this goal. This same plan also shows an energy policy that calls for the rationalization of coal transport by rail and the shifting of the transport of coal by road to ships and railways.

Table 2-1 Main Infrastructure Investment Targets in the 10th 5-Year Plan

Roadways	A 2,000 km extension of national roadways. The construction of 5,846 km of trunk roads for the Golden Quadrilateral. The construction of 7,300 km of regional-national roadways.
Railways	Providing 52,000 km of rail improvements over a broad area.
Ports	Increasing the volume of freight handled at the main ports from 289 to 415 million tons.

The following is a brief summary of the key policy items of the Plan related to railways.

- Re-evaluation of the rigid railway fees that is not appropriate for a market economy.
- Returning freight transport to Railways to counter the recent trend towards road transport in consideration of environmental issues such as exhaust fumes.
- Increasing the operating efficiency and reducing the operating expenses of the national railway which has become a gigantic organization with role of providing both the social functions for commuting in urban areas, low-cost transport for daily necessities and the commercial services for high quality transport.

The items for investment related to railways are as follows:

1) Building a stronger high-density network.
2) Increasing the transport speed by making operations more efficient.
3) Using information technology to respond to customers.
4) Using the Special Safety Fund to improve safety by replacing facilities that have exceeded their life span.
5) Reducing energy costs by purchasing energy from centralized or cogeneration plants.

6) Participating in new business ventures through PPP tie-ups.
7) Expanding the rail share of passenger and freight transport using the X Plan.

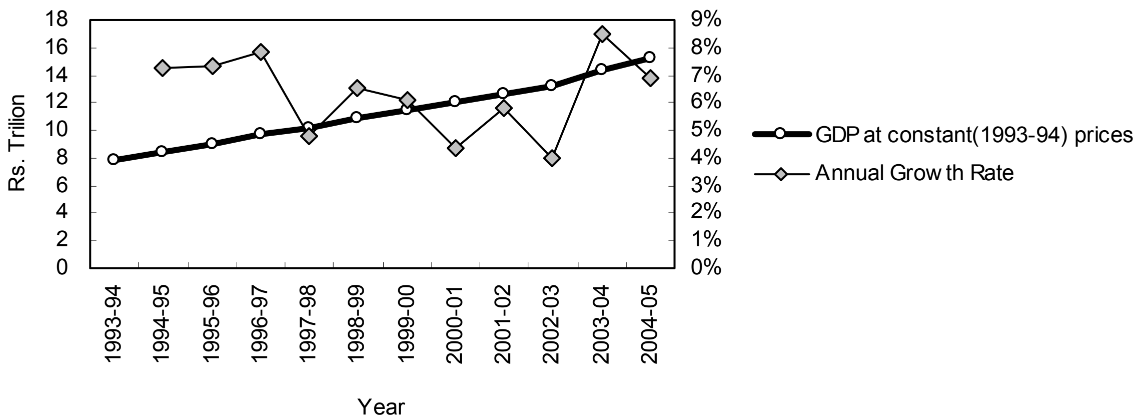
In objective terms, this includes: purchasing 65,000 freight cars capable of heavier axle loads, 343 electric locomotives and 444 diesel locomotives; refurbishing 34,990 km of track, repairing or reconstructing deteriorated bridges; improving the safety of signaling and communication equipment; and constructing 6 new track sections at Banspani – Daitari, Hubli – Akola, Jammu – Udhampur – Katra, Qazigund – Baramulla, and Kolayat – Phalodi.

2.3 ROLE OF RAILWAY IN FREIGHT TRANSPORT OF INDIA

2.3.1 Freight Transport in India

(1) Economic Growth and Transport Sector

Indian's economy has grown at an average growth rate of 6.2% as shown in Figure 2-1. The growth rate of Gross Domestic Product (GDP) was highest in 2003-04 at 8.5%. The compound annual growth rate (CAGR[1]) from 2000-01 to 2004-05 works out to be 6.3%, while it was also 6.3% from 1993-04 to 2000-01.



Source: Central Statistics Organization

Figure 2-1 GDP at constant (1993-04) prices and GDP Growth Rate

Transport sector accounted for 5.8% of GDP in 1999-2000, and increased to 6.5% in 2004-05 as shown in Table 2-2. Of the transport sector, railway sub-sector accounted for 18.9% in 1999-2000, decreased to 16.7% in 2004-05.

Table 2-2 Share of Transport Sector to Gross Domestic Product

(Rs. Trillion)

	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05
GDP at constant (1999-2000) prices, a	17,923	18,704	19,781	20,526	22,260	23,937
Transport Sector*, b	1,033	1,106	1,156	1,264	1,397	1,559
% share (b/a*100)	5.8	5.9	6.8	6.2	6.3	6.5
% of Railway sub-sector to Transport Sector	18.9%	18.4%	18.9%	18.3%	17.4%	16.7%

Note: *includes Railway, Transport by other means, Storage.

[1] Calculated as $\sqrt[n-1]{y_n / y_1} - 1$

(2) Modal Share

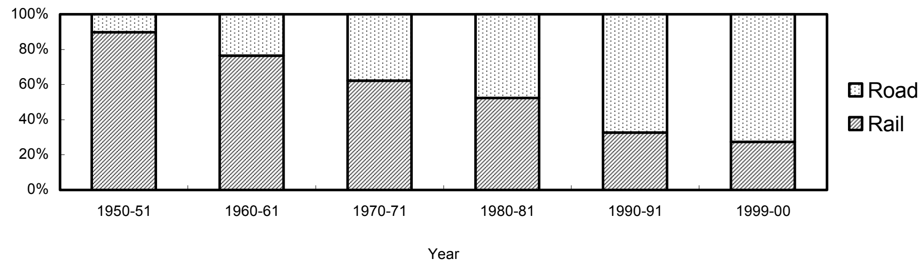
The total freight volume in India in terms of tonnes or tonne-km is not available because the estimation of the volume of freight transport by road is not clear; although some sources say that Indian transport system carry about 1,000 billion tonne-km per year. There is a calculation about modal share in India as:

Table 2-3 Modal Share for Freight Transport in India

Road	Railway	Coastal Shipping	Inland Water Transport
60%	33%	6.85%	0.15%

Source: National Maritime Development Plan, Ministry of Shipping, Road Transport and Highways

There is another calculation for a long period as shown in Figure 2-2. Railway lost its market share in land transport in the last half of the 20th century from 90% to 27%. With increasing transport demand for consumer goods, which requires flexible delivery, transport volume by road will continue growing. In addition, even a certain part of bulk transport will shift from rail to road due to rapid expansion of highway network and continuous mobilization.

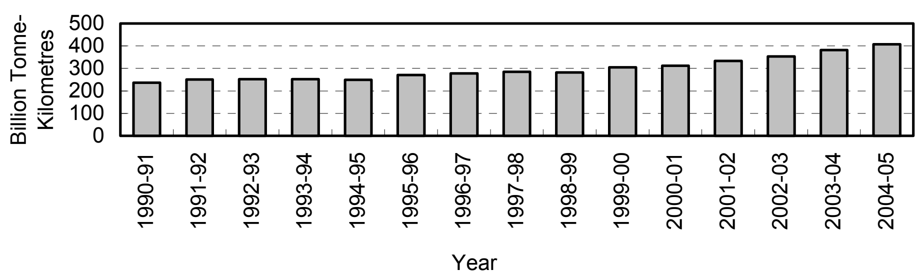


Source: Vision 2020 Transport (Original data is cited from Indian Road Congress)

Figure 2-2 Modal Share between Rail and Road (tonne-km)

(3) Railway Transport

Indian Railways carried 602.1 million tonnes of revenue earning traffic in 2004-05, generating 407.4 billion net tonne km (NTKM)[2]. Net tonne km increased at CAGR of 6.9% from 2000-01 to 2004-05, while the growth rate was small in 1990s at CAGR of 2.9% from 1990-91 to 2000-01 as shown in Figure 2-3. Considering the trend in GDP growth in 1990s mentioned above, it can be said that railway lost its market share to some extent during this period.

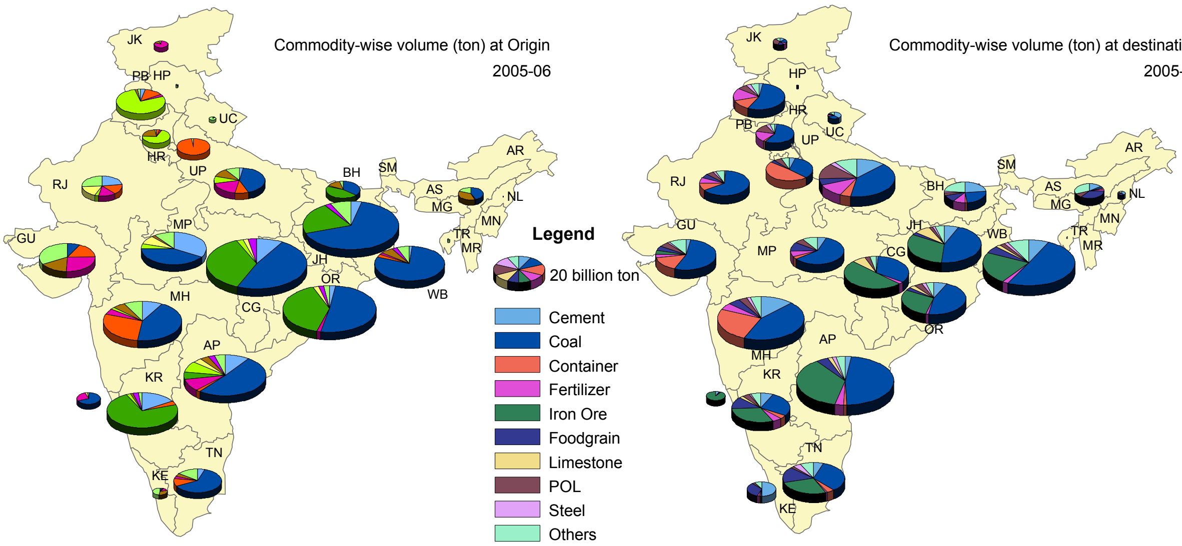


Source: Year Book, Indian Railways

Figure 2-3 Freight Transport in Tonne-Kilometres by Indian Railways (Revenue earning traffic)

2 Year Book 2004-05, Indian Railways

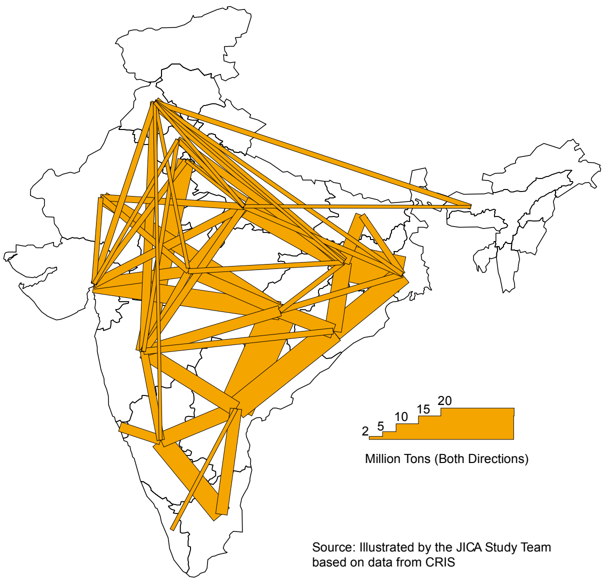
Figure 2-4 illustrates state-wise volumes of freight generation and attraction by rail. Coal transport generates in the east states (Chhattisgarh, Jharkhand, Orissa, and West Bengal) where coalfields are located, while its destinations are distributed over the country. Iron ore transport also generates in the east states (Chhattisgarh, Jharkhand, and Orrisa) but its destinations are east and east-south India. Delhi, Gujarat, and Maharashtra are the dominant origins and destinations of container traffic.



Source: Elaborated by the JICA Study Team based on CRIS data

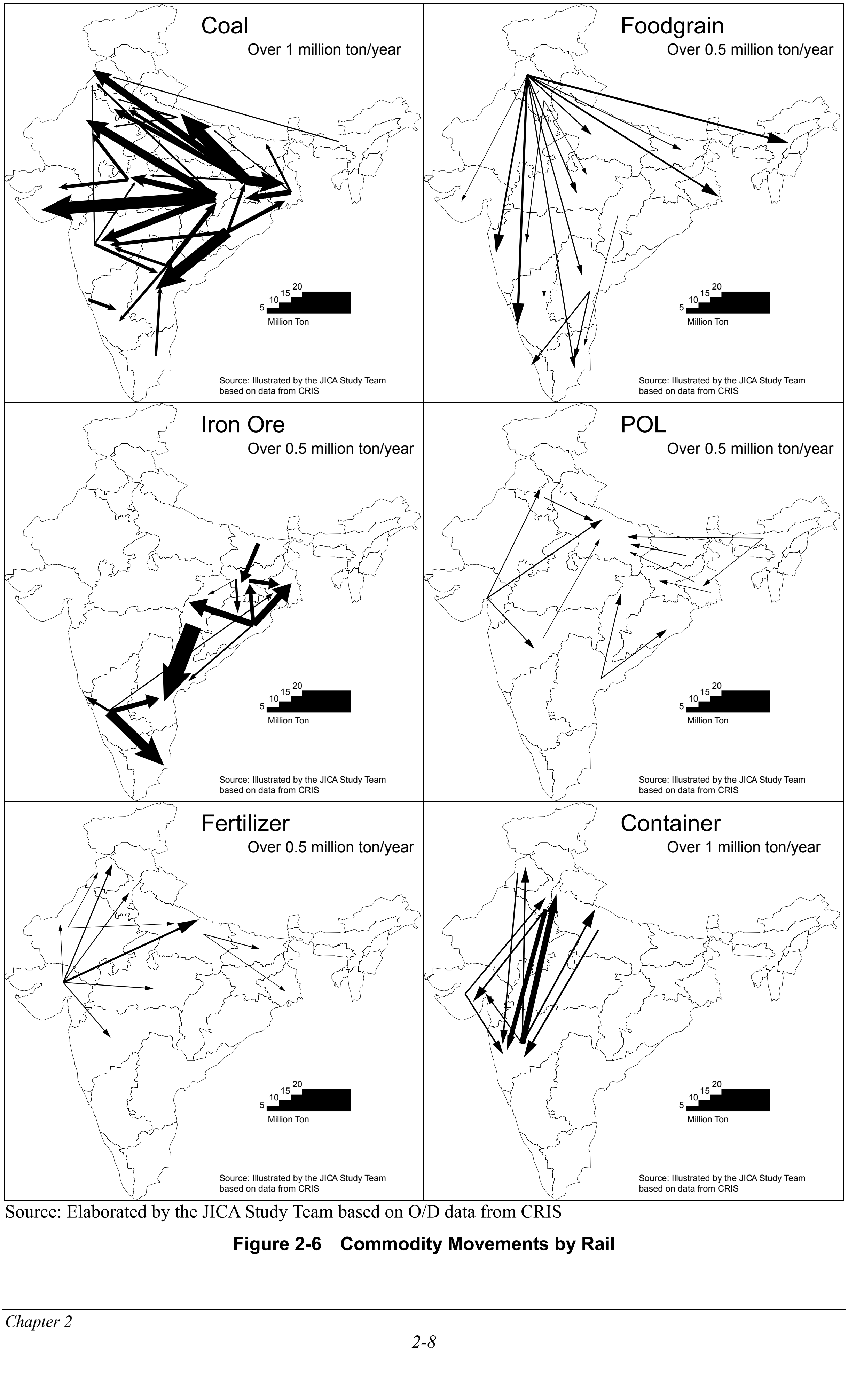
Figure 2-4 Commodity-wise & state-wise freight generation & attraction by rail (Left: generation, Right: attraction)

Figure 2-5 illustrates inter-state railway transport with lines whose width represents transport volume in tonne. From this, rail transport corridors which overlap the golden quadrilateral are observed. The thick line between Chhatisgarh and Andhra Pradesh mainly represents transport of iron ore. Coal transport accounts for the major portion of other thick lines. Figure 2-6 illustrates inter-state commodity flow by rail for major commodity groups.



Source: Elaborated by the JICA Study Team based on O/D data from CRIS

Figure 2-5 Freight O/D (2005, Over 2 million ton for both directions)



Source: Elaborated by the JICA Study Team based on O/D data from CRIS

Figure 2-6 Commodity Movements by Rail

(4) Road Transport

Past trend of road transport volume in recent years is not available. There are several estimations of freight traffic by road in tonne-kilometres for a recent year, varying from 520 billion tonne km (BTKM) to 1,100 BTKM as shown in Table 2-4. Economic Survey mentions that Indian roads carry 70% of the freight traffic in the country.

Table 2-4 Estimation of Tonne-Kilometres by Road for Year 2000

10th Five Year Plan	Road India*1	National Maritime Development Plan	Fact Sheet, Press Information Bureau
520 BTKM (1999-00)	1,100 BTKM (2000)	600-650 BTKM	1,136 BTKM (2001)

Note: These sources indicate the figure for tonne-km in 1950-51 as 6 BTKM
*1 Department of Industrial Policy & Promotion Ministry of Commerce & Industry

Trucking Industry

According to World Bank[3], freight transport by road in India increased at an annual average growth rate of 12% in 1990s. The number of goods vehicles was 3.5 million in 2003 (as of 31st March) [4]. It increased at a CAGR of 8.2% in 1990s and a CAGR of 8.3% from 2000 to 2003.

The trucking industry in India is competitive in freight transport sector, offering very low rates. On the other hand, profit is so small in competitive market with low rates that service quality tends to be very poor. Travel speed is relatively slow. For example, it takes three days between Delhi – Mumbai (1,400 km). Administrative check at state borders is one of the factors for delay.

Owner operators in the trucking service are in majority, and the size of their enterprises is generally small. According to Transport Corporation of India (TCI), one of the largest trucking companies in India, unorganised sector[5] accounts for 86% of the entire road freight market.

The major vehicle types are 2 and 3 axle rigid trucks with low cubic capacity. Trucks on Indian roads are generally old with out-dated technology.

Infrastructure

It is often mentioned that road network of India is insufficient and this is a potential obstacle to economic growth, although Indian road network of 3.34 million km is second largest in the world. The length of expressway is only 200km, while that of National Highways is 66,590 km as shown in Table 2-5. Four or more lane-roads account for 12% of the total length of National Highways.

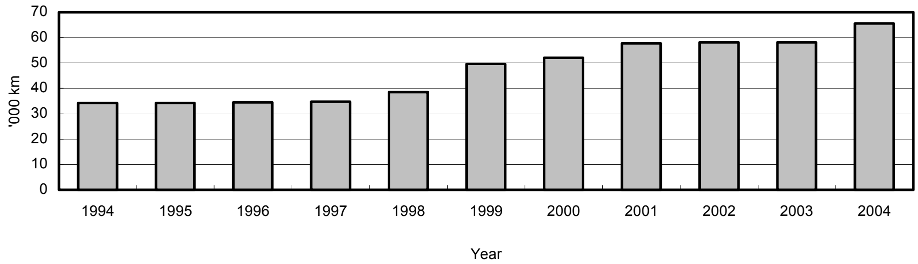
Table 2-5 Length of Roads by Category

Expressway	National Highways	State Highways	Major District Roads	Rural and Other Roads
200 km	66,590 km	128,000 km	470,000 km	2,650,000 km

Source: Road Sector On Fast Track, Ministry of Shipping, Road Transport & Highways

[3] India's Transport Sector: The Challenges Ahead, May 10, 2002
[4] Ministry of Shipping, Road Transport & Highways
[5] Individual or enterprises less than 10 employees

National Highways expanded its network in the last 10 years by 92%, from 34,200 km in 1994 to 65,569 km in 2004 as shown in Figure 2-7. Upgrading of parts of State Highways in the 9th Five Year Plan was one of the reasons of the expansion.



Source: Economic Survey, Department of Road Transport and Highways (morth.nic.in)

Figure 2-7 Length of National Highways (1994-2004)

Currently, the National Highways Development Project (NHDP), the largest highway project in India, is underway to upgrade two-lane roads to 4 or more lane roads along major corridors. The total cost is estimated to be US$ 13.2 billion (on 1999 prices). The NHDP consists of:

1) The Golden Quadrilateral (5,846 km)
2) The North-South and East-West Corridor (7,300 km)
3) Port Connectivity and other projects (1,133 km)

The Golden Quadrilateral connects four major cities of Delhi, Mumbai, Chennai and Kolkata. Delhi - Mumbai Corridor has already completed and 431 km sections remain on other corridors. The North – South Corridor connects Srinagar and Kanyakumari, and the East-West Corridor connects Silchar and Porbandar. The corridors are illustrated in Figure 2-8.

Source: National Highway Authority of India (www.nhai.org)

Figure 2-8 National Highways Development Project I & II

In 1995, the National Highway Act was amended so that toll collection on selected sections of the National Highways is possible, which enable the private sector to participate in highway development.

(5) Inland Water Transport and Coastal Shipping

Inland water transport (IWT) plays a small role in freight transport in India, carrying only 2.5 billion tonne-km a year, even though India has over 14,500 km of rivers and canals where IWT is possible. Freight traffic of IWT in 2004-05 doubled since 2000-01, from 22.2 to 45.5 million tonnes. There are three waterways that have been declared as National Waterways as shown in Table 2-6.

Table 2-6 List of National Waterways

Name	Section	Length	'000 Tonnes (2004–05)
The Ganga	Haldia – Allahabad	1,620 km	887
The Brahmaputra	Dhubri – Sadiya	891 km	819
West Coast Canal	Kottapuram – Kollam	205 km	1,054

Source: Annual Report 2004-05, Inland Waterways Authority of India

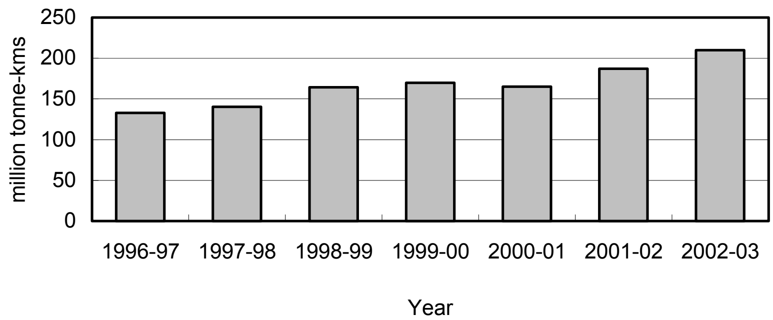
India has a long coastline of 7,517km, and coastal shipping plays an important role along the coastline. Coastal traffic accounts for 28% of the total traffic handled at all ports in India[6].

(6) International Shipping

See Chapter 4.2 "Present Condition and Future Development Plan of Target Ports".

(7) Air Cargo

Traffic volume by air transport is negligible in freight transport sector. Air transport carried 198,000 tonnes of domestic freight (including mail) in 2003-04, generating 210 million tonne km (Indian domestic scheduled operations). Except for year 2001, air cargo traffic has been increasing steadily as shown in Figure 2-9. The traffic increased by 12.3% from 2001-02 to 2002-03.



Source: Statistical Abstract 2004-05

Figure 2-9 Cargo Traffic by Air (Freight + Mail)

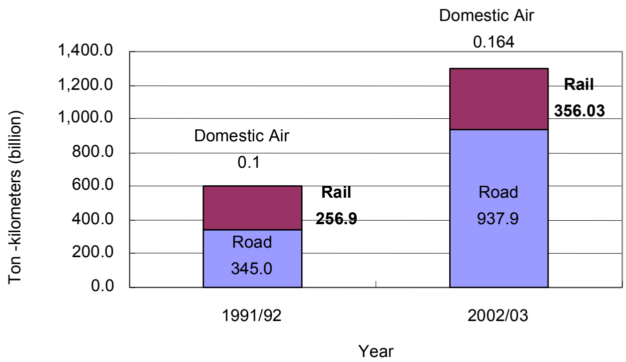
[6] Report on the Development of Coastal Shipping

2.3.2 Comparison of Rail Freight Transport with other Transport Modes

This section compares the freight transport on Indian Railways with other modes of transport, such as road and air, and identifies the roles and issues related to the railway. Since air freight transport is only a minute component of domestic freight transport in India, this section is limited mainly to comparing rail freight transport to road transport.

(1) Rail Transport Share and Trends

In the past, Indian Railways held a 60% share of overland transport from the 1960's to the 1970's. However, the railway share declined in recent years. (Refer to graph.) Yet the rail transport itself shows an increasing trend. Railways have not been able to latch onto the increase in transport occurring in conjunction with India's economic development. The cause of this is the limited traffic carrying capacity of Indian Railways. This has made it difficult to increase the allocation of the number of trains for freight trains to meet the demand for freight transport. However, in comparison with the road transport, the service level of railway transport is low in such areas as reliability, ease of use and price and these may also be driving down the ratio of rail transport.



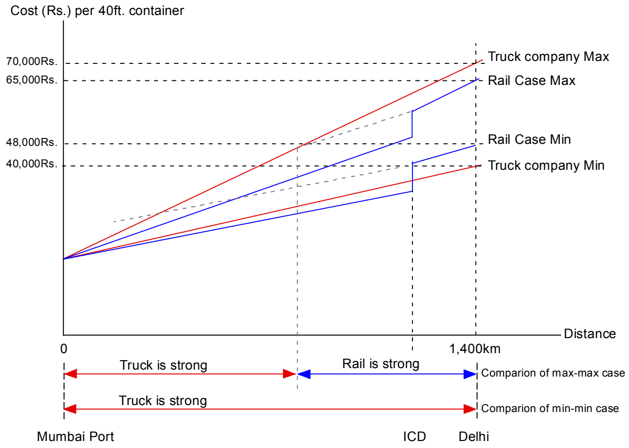
Source: Statistical Abstract of India 2003, 2002/3
Figures by JICA Study Team

Figure 2-10 Freight Demand by Mode of Transport

(2) Zones where Railways have Competitive Power

During its investigation, the Project Research Group of the JICA Study Team found that it costs Rs. 48,000 to 65,000 to transport a 40-foot container from Mumbai to Delhi by rail; it costs Rs. 40,000 to 70,000 to transport it by truck. The figure shows a comparison of costs for rail and road transport. When rail is used, a truck will still be needed to deliver the container to its final destination after it reaches to the rail station. Because of this, there will be a difference in cost at this point. As can be seen from the figure, when the freight charge for transport by truck is low, the truck offers a benefit in terms of cost. However it can also be seen that in other cases there is a point after which rail is the superior method for long-distance transport.

In recent years, Indian Railways has yielded the transport of small unit loads to nearby destinations to trucks and is concentrating on providing transport between points that have large-unit freight loads. The results shown above may also be the results of these facts and coincidences.



Source: JICA Study Team

Figure 2-11 Rate of Freight by a Single Mode and Mixed Mode

(3) Characteristic Trends of Railway Transport in such Areas as Arrival time and Punctuality

The average time required for a container to travel between New Delhi and Mumbai is 40 hours. This is approximately half of the 70 to 100 hours required for truck transport. In addition, there are many problems with road transport. Road conditions are poor, punctuality is rare and the potential for traffic accidents is high.

However rail transport has its own issues with punctuality, which are presented below. There are no schedules for freight trains, which mean that there is no regular operation. And there is no regulation of the handling containers such as the first-in first-out. So once the containers have been carried to a station, the time needed for their transport can vary by days. But this issue is something that the railroad can solve by itself.

Indian Railways is currently constructing the Freight Operation Information System that could resolve these weak points. Some functions of this system are already in operation. This system records the time that the freight train actually passes through each station and is intended to gather information about the current position of the freight train at the related locations. This will be also achieved if the freight trains have a timetable. Once this is completed, the plan is to provide various information services using this data.

2.3.3 Freight Transport on Existing Lines

(1) Railway Freight Transport Volume

Indian Railways freight transport tonnage is 626.2 million tons. The annual (2004 to 2005) transport tonne km is 407,398 million tonne km. This is 12 times the tonnage transported in Japan and some 18 times of its transport tonne km.

The eight main types of freight transported are, coal, iron ore, iron products, fertilizer, grain, cement, limestone and petroleum.

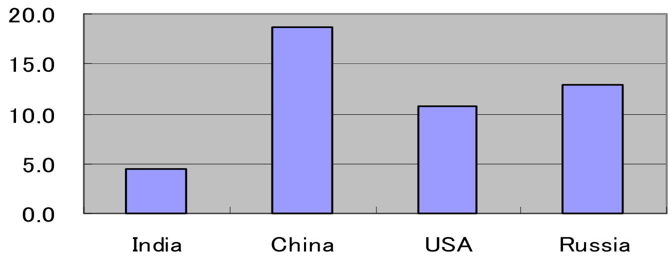
Railways also have a high position in the Golden Quadrilateral. These railways have a total length of 9,935 km and this is only 16% of the entire network. Freight accounts for 65% of the total amount transported on these lines.

(2) Various Factors of Freight Transport and their Features

From 1991, Indian Railways changed from a gather-and-transport system, in which freight trains were arranged in yards, to a system that provided direct transport between two main points. This made spending time in the yard unnecessary and simplified the transport system.

The freight trains characteristically handle large transport units with container trains transporting 3,385 tonnes (carrying 90 TEU per train) and regular freight trains transporting 4,715 tonnes (3,400 tonne load) per train.

Freight trains on Indian Railways do not use a schedule. Once the freight for one train has been gathered, transportation arrangement is procured and the freight train leaves the station in conjunction with an open interval in passenger train operation. Container trains are comprised of rolling stock with a maximum speed of 100 km/h and travel concurrently with passenger trains. Regular freight trains have a maximum speed of 75 km/h. However, since passenger trains have track priority along the way, the average speed of freight trains with stopping time is included is said to be 20 to 30 kilometers per hour.



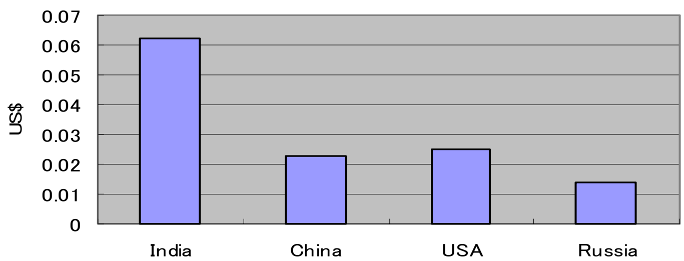
Source: India's Transport Sector WB 2002

Figure 2-12 Ton-km/Route Length

(3) Comparisons with other Countries

This section compares the freight transport volume on Indian Railways with other countries that have a large land mass. (Refer to Figure 2-13.) In India, the transport tonne km is relatively small in relation to total track length. The passenger km ratio in India is 63%, which is relatively high when compared to 38% in China and 41% in Russia.

And when the level of rail freight rates in India are compared with other countries with large land masses and adjusted for purchasing power parity, it shows that the freight rate per tonne km is US$0.062, which is dramatically higher than freight rates found in other countries. From these factors we can surmise the railways have overwhelming competitive superiority because of the underdeveloped roadways.



Source: India's Transport Sector WB 2002

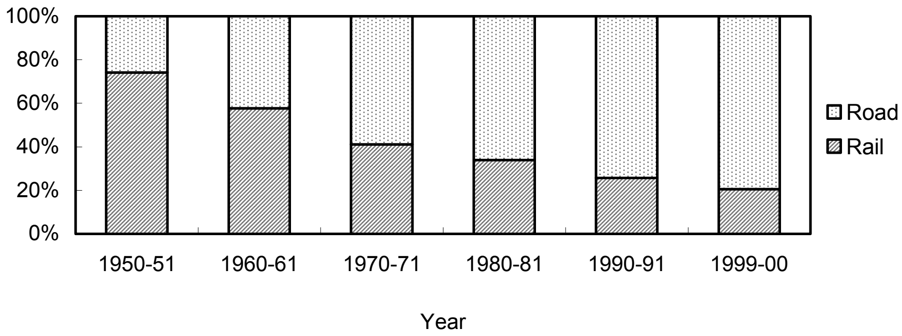
Figure 2-13 Freight Revenue per ton/km (PPP)

2.4 PASSENGER TRANSPORT

2.4.1 Passenger Transport in India

(1) Modal Share

Passenger traffic has risen from 23 Billion Passenger km (BPK) in 1950-51 to 2220 BPK in 1999-00, according to 10th Five Year Plan. There are some estimates about passenger traffic volumes in 2000, varying 1,880 BPK to 4,000 BPK. The recent figures are not available in officially published documents because estimate of passenger-km by road is not clear. There is a calculation of passenger-km by land transport for the past trend as shown in Figure 2-14. The chart indicates that Railways' share dropped from 74% in 1950-51 to 21% in 1999-00.



Source: Vision 2020 Transport (Original data is cited from Indian Road Congress)

Figure 2-14 Modal Share of Passenger Transport between Rail and Road

Indian Railways carried 5.4 billion passengers with 576 BPK in 2004-05. The number of domestic passengers by air in 2004-05 was 19.4 million, and the passenger-km was 18.0 BPK. Table 2-7 indicates passenger traffic volume by different mode.

Table 2-7 Passenger Traffic by Mode

	SRTUs*	Indian Railways	Indian Domestic Airlines
No. of passenger (million)	19,361	5,378	19.4
Passenger-km (BPK)	410.3	576	18.0

Note: SRTU – State Road Transport Undertakings
Source: /1) Association of State Road Transport Undertakings (www.asrtu.org) /2) Year Book 2004-05, Indian Railways, /3) Directorate General of Civil Aviation (www.dgca.nic.in)

(2) Railway

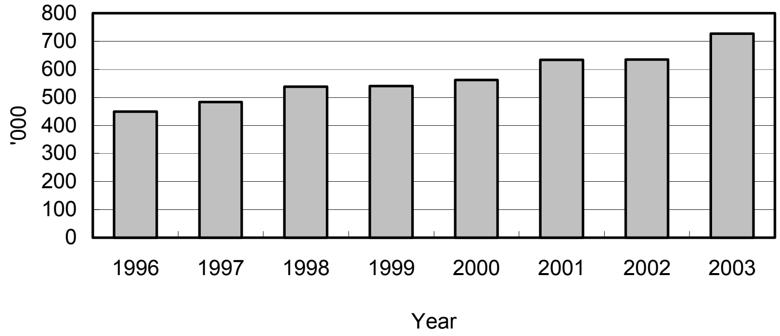
The railway network covers all India with the total track length of 63,000 km. The Indian Railways play an important role in passenger transport in India, providing passenger services for suburban trains (commuter), non-suburban trains including ordinary and express and mail. Night trains are very important transport method for long distance travel such as Delhi – Mumbai, Delhi – Kolkata, Mumbai – Kolkata, and so on, even with the rapid increase in air services between major cities in India. Passenger trains are always crowded, especially suburban trains and second class of long-distance trains. Quality of second class service is very poor.

(3) Road (inter-city/ inter-state bus service)

According to Economic Survey, Indian roads carry about 85% of passengers in India. Road transport services are provided by both private and public sector. Public sector, mainly the

State Road Transport Undertakings (SRTUs), provides about 30% of intercity bus service. With rapid development of road network, long-distance bus operators that offer high level of service are getting into the market. For example, Raj National Express provides inter-city transport services based on Mumbai with luxury Volvo coaches.

Bus population grew slightly faster than GDP recently. The number of registered buses increased at CARG of 7% from 1996 to 2003, and reached 727,000 in 2003 (March 31) as shown in Figure 2-15

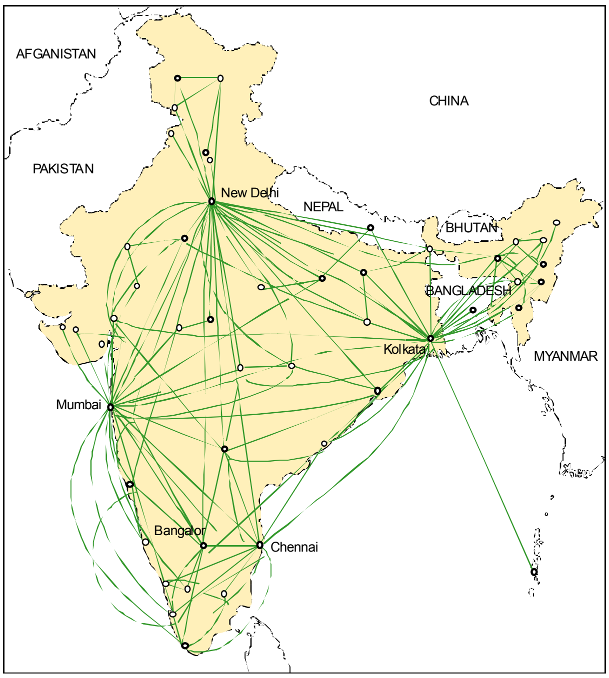


Source: Department of Road Transport and Highways

Figure 2-15 The Number of Registered Buses

(4) Civilian Air Travel

There are 449 airports/airstrips in India. International airports are Mumbai, Delhi, Chennai, Kolkata and Thiruvananthapuram. Out of these, there are some airports having customs and immigration facilities. These include Bangalore (CE), Hyderabad, Ahmedabad, Calicut, Goa (CE), Varanasi, Patna, Agra (CE), Jaipur, Amritsar, Tiruchchirapalli, Coimbatore, and Lucknow. Flight network mainly connects Delhi, Mumbai, Kolkata, Chennai, and Bangalore as shown in Figure 2-16.

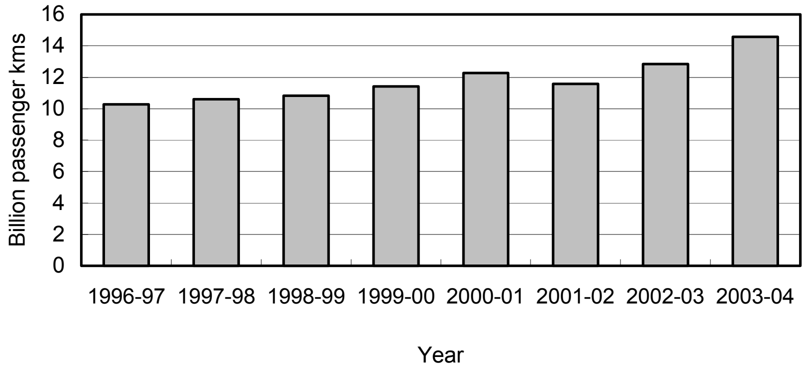


Source: JICA Study Team

Figure 2-16 Air Route Map

The air services of India were liberalized in 1994 after the repeal of the Air Corporation Act. A few private operators began air services including low-cost carriers. Currently, there are a number of airlines such as Indian Airlines, Air India, Jet Airways, Air Sahara, Alliance Air, Air Deccan, Spice Jet, Kingfisher Airlines, GoAir, and so on.

Although there was a drop in 2001-02, air passenger traffic grew at 6% in the last five years as shown in Figure 2-17.



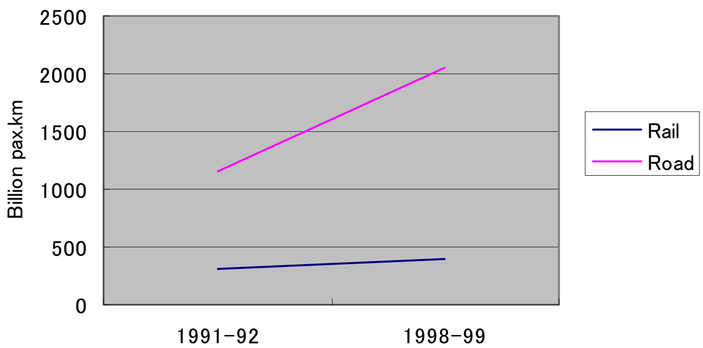
Source: Statistical Abstract

Figure 2-17 Passenger-km of Domestic Airlines

2.4.2 Comparison of Rail Passenger Transport with other Transport Modes

(1) Rail Transport Share and Trends

The Figure 2-18 shows the trends in passenger transport. Since the air transport share is less than 1%, the comparison is limited to rail and road transport. We can read the share of railways in passenger transport from these data, too. Both rail and road are expected to increase its volume as the GNP grows with an annual growth rate of 7 to 8 percent. Road transport shows an 8.4% growth rate that exceeds this, while rail growth does not exceed 3.6%. In addition, the rail share has fallen from 21.3% to 16.5% over seven years.



Source: India's Transport Sector WB 2002

Figure 2-18 Road vs Rail (Passenger-km)

(2) Controlled public passenger fare levels

The minimum fare of Indian Railways is as low as four rupees. The minimum fare for all forms of public transportation, including subways and buses, is the same. It is said that this is in consideration of the burden to the low-income class. Because of this, overall public passenger service of Indian Railways is in operational loss.

On Indian Railways nearly all long-distance passenger trains are express trains. The fare system is arranged so that the revenue from the upper class passengers covers almost their expenditures. However, the low revenue from second class passengers, who make up the vast majority of passengers, along with low-revenue transport in urban areas, generates a large amount of the deficit. (See Figure 2-19)

Source: India's Transport Sector WB 2002

Figure 2-19 Ratio of Second Class Passenger km and Earnings

(3) Characteristics of Rail Transport in such areas as Traveling Time, Punctuality and Comfort

India is a vast country. Because of this, there are many air routes that offer shorter travel times and higher security compared to the railway. However, at this point in time, number of cities that have airports is relatively small in comparison to the vast size of the country. Moreover, since there is a limited number of routes and flights for air transport services, there are many cities that can only be reached by rail.

Because of this, providing high-speed passenger service by Indian Railways has become a major issue. Already there are express trains named as Shatabdi, Rajdhani and other special trains that travel at a maximum speed of 130 km/h. While expressways are being developed, nearly all people use rail travel when traveling between cities because the travel time is shorter than by automobile. However, there are cases where people will travel by car because of the low frequency of the trains and their late-night operating schedules.

Passenger trains are operated daily according to publicly displayed train schedules. When trains have delay of 15 or more minutes at the borders of the zonal railways, it is identified as train delay. Based on this standard, the normal operating punctuality is 96.3%. Further, because of this, the punctuality of rail travel is higher than that of intercity bus service, which faces bad road conditions and hence unpredictable travel times.

Most of the larger stations are already located at city centers. These stations are crowded with people. It is difficult to say if railway security is higher than other forms of public transportation. Long-distance trains offer reserved seats and air-conditioned first class coaches, making it a comfortable way to travel. However, the unreserved seats on these trains and on the local trains serving nearby stations are overflowing with passengers. It would be difficult to describe these coaches as comfortable. Passengers traveling on buses also face the similar conditions.

2.4.3 Passenger Transport on Existing Lines

(1) Transport Factors for Passenger Trains.

The passenger km of Indian Railways is 57.57 billion passenger km, of which 22% comes from urban transport in the cities of Mumbai, New Delhi, Calcutta and Chennai. Incidentally, the passenger transport km of railways in Japan for the same period were 38.517 billion passenger km.

On the routes that connect major cities there are express trains that connect the major cities and the local trains that provide transport services to nearby stations. On busy sections, some 50 one-way trains are operated. Most of the other sections have less than five round-trip trains are operated. There are even sections that have only one train a day. The average travel distance per passenger is 214.5 kilometers when urban area transport is not included. So it can be presumed that not all operating sections of long-distance railways necessarily have this heavy rider ship.

In general, the trains are quite long with some having up to 24 coaches.

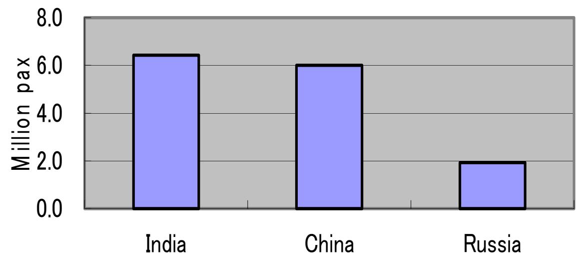
The ratio occupied by the Golden Quadrilateral against the total rail passenger transport is 55%.

(2) Other Features

Indian Railways has a transport system centered on long-distance trains for serving the vast expanse of the country. The concept for train operation is to set up trains to match the forecasted rider ship in a section. These trains can be up to 24 cars long (18-car trains are also used in some sections). As a result, there are many cases where operation is set for only one day per week. (The plan is such that on the days when there is no operation, trains from other stations use the same schedule for operating on the trunk sections.) Many of the long-distance trains take more than one day to reach their destinations. Because of this, many of the coaches on long-distance trains are sleeper coaches. This is based on the concept that the operating schedules for most of these trains are for sleeping at night.

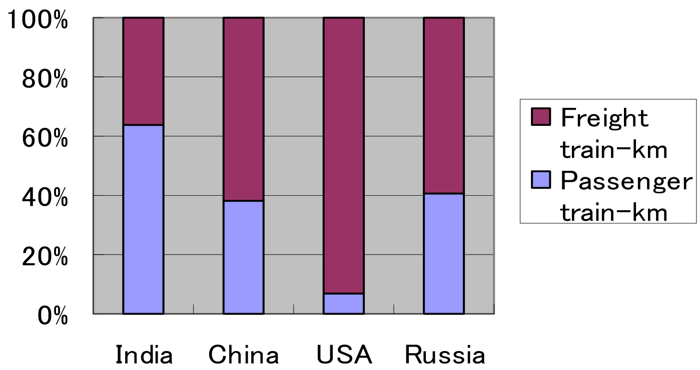
(3) Comparison of Passenger Transport with other large Landmass Countries

In this section passenger transport in India is compared with other large landmass countries such as China and Russia. The United States is not included in this comparison because passenger rail transport has declined there to a level where it occupies only a small percentage of total passenger transport. The first comparison is in terms of the scale of passenger transport. In a comparison of transport passenger kilometers and route length, India and China have particular similarities (See Figure 2-20). However, in a comparison of all train kilometers, it can be seen that the percentage occupied by passenger transport is 64% in India, 41% in Russia and 38% in China, indicating that the Indian railway is mainly used for passenger transport. Indian Railways has this one special characteristic (See Figure 2-21).



Source; Indian transport sector WB2002

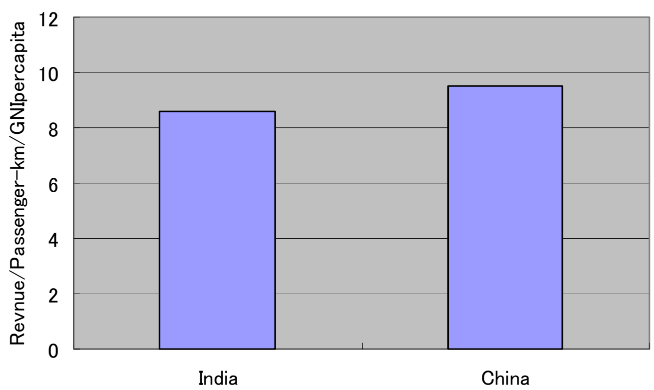
Figure 2-20 Passenger km/Route km



Source: UIC statistics 2003

Figure 2-21 Ratio of Two Categories of train-km

By the way, in the position paper of the World Bank Group it was pointed out that the fare level of the passenger on Indian Railways is relatively low compared with the level of rail freight rates. The comparison of passenger fare revenue per passenger- km of China and India, compensated with GNI per capita (the data of Russian Railways was not available) derived from International Railways Statistics 2002 by UIC tells us that the fare level of Indian Railways is not so different as in other countries. If it were extremely low, problem would lie, due to government control on the fare structure.



Source: UIC Railway statistics in 2002 and WB database

Figure 2-22 Revenue per Passenger-km

CHAPTER 3
SOCIO-ECONOMIC CONDITION OF THE CORRIDORS

CHAPTER 3 SOCIO-ECONOMIC CONDITION OF THE CORRIDORS

3.1 INTRODUCTION

The Eastern and Western Corridors form two sides of the Golden Quadrilateral (GQ), connecting three apexes – Mumbai, Delhi, and Kolkata.

To analyze socioeconomic condition, the following data have been collected:

Category	Item	Source
Population	Village level by rural/urban, sex, and age-group	Census 2001 Statistical Abstract
Area	District level	Statistical Abstract
Economic activity	Gross State Domestic Product (GSDP) Net State Domestic Product (NSDP) Per Capita GSDP & Per Capita NSDP (at current prices & constant prices from 1993-04)	CSO
Industry	Outlook of steel industry in India Outlook of coal industry in India Outlook of mining industry in India	Ministry of Steel Ministry of Coal Ministry of Mining
Agriculture	Production by crop	Statistical Abstract

In addition to the above, major sources of this Chapter are the RITES-F/S and "Data Collection for Dedicated Freight Corridor Project, May 2006, JICA".

3.2 REGIONAL PROFILE

The Eastern and Western Corridor cross ten states in northern India. The Western Corridor crosses five states – Maharashtra, Gujarat, Rajasthan, Haryana, and Delhi. The Eastern Corridor crosses seven states – West Bengal, Bihar, Jharkhand, Uttar Pradesh, Delhi, Haryana, and Punjab.

Figure 3-1 States in India

Table 3-1 State Profile

	Area ('000 sq km)	2001 Population (million)	Decennial Growth Rate (%)	Urban Population Rate (%)	Sex Ratio *1	Per Capita NSDP (Rs.)
West Bengal	88.8	80.1	17.8	28.0	934	22,497
Bihar	94.2	82.9	28.6	10.5	921	5,772
Jharkhand	79.7	26.9	23.4	22.2	941	13,013
Uttar Pradesh	294.9	166.2	25.9	20.8	898	11,477
Haryana	44.2	21.1	28.4	28.9	861	32,712
Rajasthan	342.2	56.5	28.4	23.4	910	16,212
Gujarat	196.0	50.7	22.7	37.4	921	28,355
Maharashtra	307.7	96.8	22.7	42.4	922	32,170
Punjab	50.4	24.4	20.1	33.9	704	30,701
Delhi	1.5	13.4	47.0	93.2	821	53,976

Note: *1) Females per 1000 males *2) Net State Domestic Product 2004-05, (current prices)
Source: Statistical Abstract 2005-06 (Census-2001), CSO (mospi.gov.in)

(1) Eastern Corridor

West Bengal

West Bengal is located in eastern India, bordering on Bangladesh. The Bhagirathi River, a branch of the Ganges River, flows in West Bengal. The state capital, Kolkata, is the centre of eastern India. Having Haldia Port and Kolkata Port, Kolkata is also the important gate for Nepal. Agriculture, including tea product, is the major industry. The population of West Bengal is 80.1 million.

Bihar

Bihar is located on the east of Uttar Pradesh, bordering on Nepal in the north. The Ganga River flows through Bihar Plain from west to east. Bihar has a rich history. Buddhism and Jainism originated in Bihar. Economic level is very low, with the least per Capita GSDP of Rs.5,659 (2001). Agriculture is the main industry. The population of Bihar is 82.9 million.

Jharkhand

Jharkhand, located to the south of Bihar, separated out from Bihar in 2000. Jharkhand is rich in mineral resources. It is famous for steel plants located in Bokaro and Jamshedpur (Tatanagar), owing to large deposits of iron ore and coalfields. Total population of Jharkhand is 26.9 million.

Uttar Pradesh

Uttar Pradesh (UP) borders on Nepal to the north. The area of 236,286 km^2 is larger than that of Nepal. The Gangetic plain stretches across the entire length of UP from east to west. The Ganges River flows in the south from west to east. Often referred to as the "cow belt" or "Hindi belt", Uttar Pradesh has been the most dominant state in Indian politics and culture since Independence. Agriculture is the major industry. There are many tourist attractions such as Taj Mahal in Agra, Varanasi, Allahabad, and so on. The population of UP is as large as 166 million.

Punjab

Punjab is the location of the Indus Valley Civilization. The state borders on Punjab State in Pakistan. Punjab is rich in agricultural product such as wheat and rice. The land is so fertile that Punjab export agricultural products to other states. The population of Punjab is 24.4 million.

(2) Western Corridor

Haryana

Haryana borders on Delhi. Gurgaon and Faridabad are emerging satellite cities of Delhi as industrial centres for information technology. Haryana is an industrialized state, producing cars, motorcycles, steel, textile, and so on. Hero Honda, Maruti Udyog Limited, Alcatel, Sony India, and other famous industrial company's are located in the state. On the other hand, agriculture has been the major industry of Haryana, exporting food production to other states. Wheat and rice are the major crops. The total population is 21.1 million.

Rajasthan

Rajasthan is the largest state of India, having an area of 342,239km^2. With its rich historical and cultural heritages, there are many cities that attract tourists. Thar Desert covers western Rajasthan. The northwest tract is sandy and unproductive with little water. The Aravalli Range stretches in the east-south of the state. Agriculture is the main industry. The total population is 56.5 million.

Gujarat

Gujarat faces the Arabian Sea. The large peninsula of Kathiawar lies between the Gulf of Kutch and the Gulf of Khambhat. Gujarat is the most industrialized state in India. Gujarat is the largest producer of salt in India. Ahmedabad, the former state capital, is a big city with a population of 5.8 million, and plays an important role of the commercial centre of Gujarat. The population of Gujarat is 50.7 million.

Maharashtra

Maharashtra is located on the south of Gujarat, facing Arabian Sea. The gross state domestic product (GSDP) of Maharashtra is the largest in India, accounting for 13% of the gross domestic product (GDP). The state capital is Mumbai, the largest city in India with a population of about 12 million. Mumbai is not only the industrial centre, but also the commercial centre (Bombay Stock Exchange) and cultural centre (Bollywood). Having Mumbai Port and JNPT, Mumbai is the western gate of India for foreign trade. The population of Maharashtra is 96.8 million.

3.3 DEMOGRAPHIC CONDITION

The total population of the 10 states are more than 620 million. The population of Delhi grew by 47% for 10 years from 1991 to 2001. The increase rates of other states for the same period varies from 18% to 29%.

The increase rate of West Bengal was the lowest at about 18%. The increase rates of Punjab, Maharashtra, Gujarat, and Jharkhand were 20 – 25%, while those of Bihar, Haryana, Uttar Pradesh, and Rajasthan were 25 – 29%.

The sex ratio of India shows demographic imbalance between men and women. Female population is lower than male population in all the states along the Corridor. Migration of male labours to larges cities is only a small reason. It can be attributed to the discrimination that girl child faces and the consequential problems of poor health and nutritional status.

Delhi has been growing faster than other mega cities. There are more than 17 cities with the population of more than a million along the Corridors such as:

Table 3-2 List of Million plus City

State	City	Population (million)
Delhi	Delhi U.A	12.9
Haryana	Faridabad (M Corp.)	1.1
Gujarat	Ahmedabad U.A	4.5
	Rajkot UA	1.0
	Surat UA	2.8
	Vadodara UA	1.5
Rajasthan	Jaipur (M Corp)	2.3
Maharashtra	Greater Mumbai UA	16.4
Uttar Pradesh	Allahabad UA	1.0
	Agra UA	1.3
	Kanpur UA	2.7
	Lucknow UA	2.2
	Varanasi UA	1.2
West Bengal	Kolkata UA	13.2
	Asansol UA	1.1
Punjab	Ludhiana (M Corp)	1.4
	Amristar UA	1.0

Source: Census of India (www.censusindia.net)

Indian society is complex. Besides the federal's official language of Hindi, 17 languages are used as official languages of 28 states. Although Hinduism is the major religion in India, there are many other religious groups such as Muslims, Sikhs, Christians, Buddhists, Jains and so on. Scheduled castes and scheduled tribes account for 16.2% and 8.2% of the total population of India.

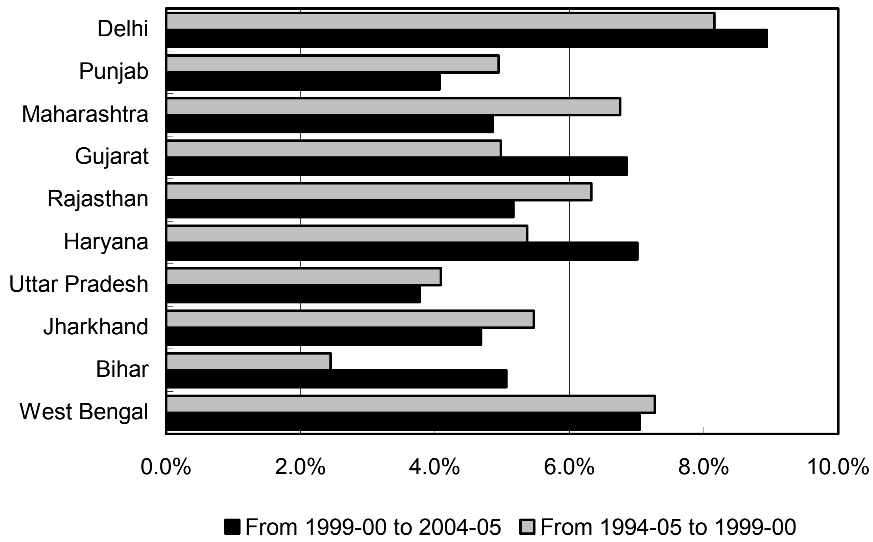
Table 3-3 Official Languages, % of scheduled castes and tribes, literacy rate and poverty ratio

	Official Language	% of scheduled castes	% of scheduled tribes	Literacy Rate (%)	Porvety Ratio
West Bengal	Bengali	23.0	5.5	69	6.3
Bihar	Hindi, Angika, Bhojpuri, Magahi, Maithili	15.7	0.9	47	14.1
Jharkhand	Hindi	11.8	26.3	54	N.A.
Uttar Pradesh	Hindi, Urdu	21.1	0.1	56	12.9
Haryana	Hindi, Punjabi	19.3	NST	68	5.0
Rajasthan	Hindi, Gujarati	17.2	12.6	60	4.7
Gujarat	Hindi, Rajasthani	7.1	14.8	69	3.9
Maharashtra	Marathi	10.2	8.9	77	11.4
Punjab	Punjabi	28.9	NST	70	0.9
Delhi		16.9	NST	82	N.A.

Note: NST – No Scheduled Tribe notified
Source: Statistical Abstract 2005-06, indiastat.com

3.4 ECONOMIC CONDITION

Figure 3-2 illustrates CAGRs of Gross Domestic Product (GSDP) for two periods of last 10 years. Economic growth of Delhi has been significant for the last 10 years. GSDP of Delhi doubled since 1994-05 at CAGR of more than 8%. West Bengal is also one of the fastest growing states. During the five years from 1994-05, GSRD of West Bengal grew at a CAGR of 7.3%, keeping the high growth during the five years from 1999-00 at a CAGR of 7.0%. Haryana and Gujarat also have performed high economic growth for the recent five years at a CAGR of 7%. Economic growth of Rajasthan and Maharashtra became slow from CAGRs of over 6% in the second half of 1990's to those of about 5% in the first half of 2000's.



Note: Black bar indicates CAGR from 1990-00 to 2004-05, while grey bar indicates that from 1994-05
Source: CSO

Figure 3-2 Compound Annual Growth Rate (CAGR) of GSDP

Economic level is totally imbalanced among various states. Per Capita Net State Domestic Product (NSDP) of Bihar is very low at Rs. 5,772 (2004-05), which is one ninth of that of Delhi. Uttar Pradesh, Jarkhand, and Rajasthan belong to poorer group with Per Capita NSDP of Rs. 11,477, 13,013, and 16,212, respectively. Despite the continuous economic growth in the last 10 years, Per Capita NSDP of West Bengal is Rs. 22,497, which is lower than that of Gujarat (Rs. 28,355), Punjab (Rs. 30,701) and Maharashtra (Rs. 32,170).

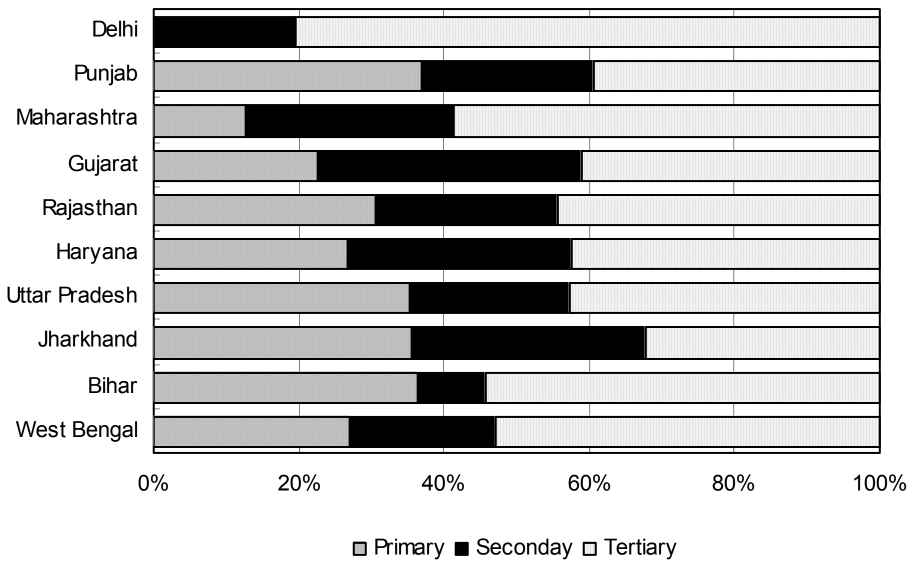
3.5 INDUSTRY

3.5.1 Overview

Roughly, the major industry in eastern parts of the Eastern Corridor is heavy industry based on rich mineral resources such as coal and iron ore. Basically, northern area around Delhi is a rich agricultural area; however, the area has been rapidly industrialized recently with high-tech industry. Western area, around Mumbai and Ahmedabad, is the most industrialized area of India.

Figure 3-3 illustrates percentages of primary, secondary, and tertiary sector in terms of GSDP by state. Secondary sector accounts for about 30% in Jharkhand, Gujarat, Haryana, and Maharashtra. Although Maharashtra is highly industrialized state, the share of secondary sector is only 29% due to high production from the tertiary sector, which is contributed to

Mumbai. Primary sector accounts for about 35% in Punjab, Uttar Pradesh, Jharkhand, and Bihar. Mining and quarrying sub-sector accounts for 40% of the primary sector in Jharkhand. There are massive coalfields and depots of iron & ore in Jharkhand.



Note: % of domestic product (at current prices) in 2003-04
Source: CSO (mospi.gov.in)

Figure 3-3 State-wise Industrial Structure

The number of factories is largest in Maharashtra at 17,570 in 2002-03, followed by Gujarat at 13,180 as shown in Table 3-4. The growth rate of the number of enterprises was highest in Haryana at 6.5%, followed by Punjab at 5.9%

Table 3-4 Factories and Enterprises

	No. of Factory (2002-03)	Net Value Added (Rs. Billion)	No. of Enterprises ('000) in 2005	Growth in enterprises from 1998 to 2005
West Bengal	6,085	7,209	4,286	4.1
Bihar	1,403	855	1,290	3.1
Jharkhand	1,417	6,916	491	3.0
Uttar Pradesh	8,980	11,365	4,016	5.1
Haryana	4,437	7,657	828	6.5
Rajasthan	5,409	4,778	1,957	3.6
Gujarat	13,180	22,889	2,419	3.4
Maharashtra	17,570	34,919	4,375	4.4
Punjab	6,987	5,485	1,072	5.9
Delhi	3,436	2,527	754	1.4

Source: Statistical Abstract, Provisional Result of Economic Census 2005

3.5.2 Sectoral Profile

(1) Steel and Iron

India is the 9th largest producer of steel in the world. Most steel plants are located in eastern area of the Eastern Corridor. Major steel plants are shown in Table 3-5:

Table 3-5 Steel Plants in proximity to the Corridors

Company	Steel Plant	Location	State	Capacity(mtpa)
SAIL	Bokaro Steel Plant	Bokaro	Jharkhand	4.6
SAIL	Rourkela Steel Plant	Rourkela	Jharkhand	2.0
SAIL	Durgapur Steel Plant	Durgapur	West Bengal	2.1
SAIL	Bhilai Steel Plant	Bhilai	Chhattisgarh	3.2
Indian Iron & Steel Co Ltd	IISCO Steel Plant	Burnpur	West Bengal	0.9
Tata Iron & Steel Co Ltd	TISCO Steel Plant	Jamshedpur	Jharkhand	5.0
Neelachal Ispat Nigam Ltd	NILT Steel Plant	Duburi	Orissa	1.5

Source: RITE-F/S, Steel Authority of India Limited. (www.sail.co.in)

Table 3-6 Production of Iron Ore (2003-04)

('000 tonnes)

Andhra Pradesh	Chhattisgarh	Goa	Jharkhand	Karnakata	Orissa	Others	Total
1,390	22,675	20,157	14,484	31,562	30,179	154	120,601
1.1%	18.8%	16.7%	12.0%	26.2%	25.0	0.1%	100%

Source: Statistical Abstract

(2) Coal

Total volume of coal reserves in India is estimated to be 253.3 billion tonnes. Table 3-7 indicates coal reserves in India. Coal reserves in Jharkhand, Orissa and Chhattisgarh, altogether account for 70% of the total reserves.

Table 3-7 Coal Reserves in India

State	Reserves (billion tonnes)	% Share	Managing Company (s)
West Bengal	27.8	11.0	Eastern Coalfields Limited (ECL)
Jharkhand	73.9	29.2	Eastern Coalfields Limited (ECL) Bharat Coking Coal Limited (BCCL) Central Coalfield Limited (CCL)
Andhra Pradesh	17.1	6.8	Singareni Collieries Limited
Chhattisgarh	41.4	16.4	South East Central Coalfield Limited (SECL)
Madhya Pradesh	19.8	7.8	Northern Coalfield Limited (NCL)
Maharashtra	9.1	3.6	Western Coalfield Limited (WCL)
Orissa	62.0	24.5	Mahanadi Coalfields Limited (MCL)
Others	2.2	0.9	-
Total	253.3	100.0	-

Source: Ministry of Coal (coal.nic.in)

(3) Cement

Cement plants are located in various places in India. Table 3-8 indicates cement production in India. Rajasthan is the major producer, having 14 plants and producing 18.7 million tonnes per year.

Table 3-8 Cement Production in India

(million tonnes)

	Capacity	Production	Consumption	No. of Plants	Location
West Bengal	3.13	3.12	6.22	4	Purulia, Durgapur, Sankrail
Bihar	1.00	0.37	3.80	1	Bahjari
Jharkhand	4.57	3.78	2.31	5	Chaibasa, Sindri, Singbhum, Khalari, Japla
Uttar Pradesh	7.31	4.23	14.12	8	Tikaria, Raebareli, Jhansi, Churk, Dalla, Chunar, Sadva Khurd, Tanda
Haryana	0.17	-	4.25	1	Charkhi-Dadri
Rajasthan	18.83	18.66	6.97	14	Lakheri, Chittorgarh, Morak, Shambhupura, Nimbahera, Mangrol, Sirohi Road, Udaipur, Pali, Beawar, Sirohi, Kota
Gujarat	17.58	11.72	8.71	11	Sikka, Ranavav, Vereval, Porbandar, Jafradad, Magdalla, Kodinar, Abdasa, Mithapur
Maharashtra	11.80	11.04	15.88	8	Chanda, Manikgarh, Hotgi, Chandrapur, Ratnagiri, Raigad, Jalgaon
Punjab	4.20	3.79	5.23	3	Ropar, Bhatinda
Delhi	0.50	-	3.75	1	Delhi

Source: Cement Manufactures' Association (www.cmaindia.org)

(4) Fertilizer

India produces 15.3 million tonnes of fertilizers per year (2004-05) as shown in Table 3-9. Gujarat and Uttar Pradesh are the major producers along the Corridors.

Table 3-9 Production of Fertilizer (2004-05)

	Production ('000 tonnes)	% Share
West Bengal	331.0	2.2
Bihar	-	-
Jharkhand	5.8	0.0
Uttar Pradesh	2,786.4	18.2
Haryana	244.5	1.6
Rajasthan	1,097.6	7.2
Gujarat	3,675.8	24.0
Maharashtra	1,115.0	7.3
Punjab	477.3	2.9
Delhi	-	-
Other states	5,599.3	36.5
Total	15,332.7	100

Source: Fertilizer Association of India (www.faidelhi.org)

(5) Agriculture

Table 3-10 shows production of selected crops. Punjab and Uttar Pradesh are the major producers of wheat and rice. West Bengal is also one of the major producers of rice. Sugarcane is mainly produced in Uttar Pradesh.

Table 3-10 Production of Selected Crops (2003-04)

('000 tonnes)

	Rice	Wheat	Oilseeds	Cotton	Sugarcane	Potatos
West Bengal	14,662	986	651	0	1,253	7,622
Bihar	5,393	3,778	125	-	4,222	1,539
Jharkhand	2,310	118	8	-	136	-
Uttar Pradesh	13,019	25,567	928	4	112,754	8,826
Haryana	2,793	9,134	990	1,405	9,340	440
Rajasthan	165	5,876	3,995	709	309	27
Gujarat	1,277	2,037	5,665	4,027	12,669	739
Maharashtra	2,839	892	2,953	3,080	26,982	74
Punjab	9,656	14,489	102	1,478	6,620	1,383
Delhi	12	102	2	-	-	1

Source: Statistical Abstract

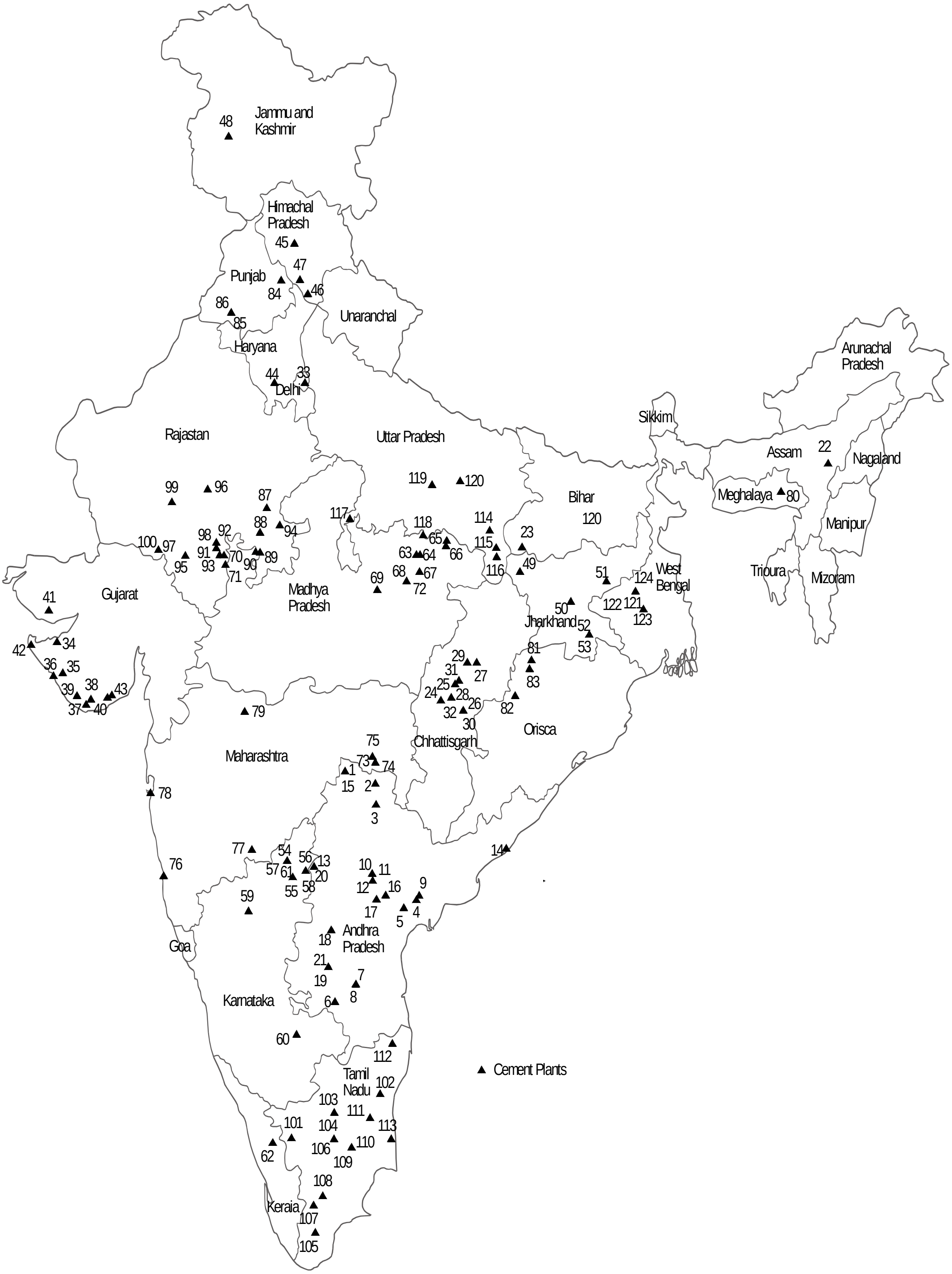
3.5.3 Location Map of Industry

Source: JICA Study Team

Figure 3-4 Location of Steel Plants in India

Source: JICA Study Team

Figure 3-5 Location of Coalfields in India



Source: JICA Study Team

Figure 3-6 Location of Cement Plants in India

CHAPTER 4
STUDY OF THE PRESENT SITUATION OF THE TARGET LINES

CHAPTER 4 STUDY OF THE PRESENT SITUATION OF THE TARGET LINES

4.1 PRESENT TRANSPORT SITUATION

In this section, train operation systems on the relevant lines are introduced and the present traffic and train operation conditions on the target lines are described in concrete terms.

In this project, the lack of line capacity on the target lines is one of the major topics to be addressed. Therefore, a close objective examination of the cause of the bottle necks that reduce line capacity is carried out.

A time table for freight train operation is not provided by Indian Railways. This is another topic to be studied indepth. The introduction of a time table for freight train operation is indispensable in enhancing the transport service level. This issue is addressed in the last part of this section.

4.1.1 Train operation systems on the relevant lines

(1) Planning and Control Organization for Train Operation

Indian Railways creates train operation plans at three levels: Railway Board, Zonal Railway and Divisional Railway, and uses these plans for controlling the operation. The former Japanese National Railways (JNR) also used to adopted this type of three-level management system. During the days of JNR, the diagram for the entire country was revised once every three years. At that time, it was very difficult work to make the adjustments among the organizations. Indian Railways is more than three times the size of JNR in terms of overall route length. Presently, Indian Railways does a good job of executing the entire operation of such a large network and organization.

Indian Railways has nearly the same amount of train kilometers per day as the former Japanese National Railways. It is forecasted that Indian Railways will operate even more trains in the future. If the organization and system of the Indian Railways for train operation remains at the same level as they are, it could be difficult to manage the future system at the existing level of efficiency. Indian Railways will need to be able to adapt and quickly respond to the change of requirements on the traffic service level that may occur in the times to come. From this point of view, it is thought that there is a need to improve the intangible measures, such as streamlining the transport system, and to construct new tangible items of the infrastructure, such as the DFC.

For example, in Japan, passenger trains on the section with small volume of passengers are operated within the section only. Trains through to another section are operated only on those sections with more number of passengers. This makes the transport system quite simple and the train operation is easy to create and control. It also helps to prevent the delay of a train in one section from affecting the schedule in another section, making it easy to improve transport quality. Of course, proper arrangement of connecting trains with other trains at junction stations is indispensable for passengers traveling over different rail sections.

(2) Train Operation and the Role of Stations

While the relevant lines along DFC are double-track, Indian Railways mainly uses an absolute block system.

The absolute block system is usually installed at stations on single track sections to enable trains to travel in different directions. Since the trains travel in the same direction on each side of the double-track sections, there is no need to provide a loop at the station for train to crossover. The main role of the station on double-track sections with an absolute block system is to facilitate the increase of the number of trains that can be operated simultaneously. At sections with automatic signals, equipment plays the role of stations. From the perspective of train operation, the role of a station in a section with automatic signals is to provide a loop for trains traveling in the same direction to pass another train.

Double tracks have always been adopted as a method for increasing the number of trains to be operated. In Japan, double-track sections have had automatic signals for a long time. Or, it may be said in another way, that there are many single-track sections that still use the absolute block system. However, this system has a train detection system that is essentially no different than an automatic signal system.

In Japan, sections with automatic signals often have a centralized traffic control system that allows the formation of routes, which was being traditionally carried out by the station staff, to be centralized in a train control center where dispatchers make routes for the trains. The installation of a centralized traffic control system makes it possible to know the latest traffic conditions, enabling more appropriate decisions to be made.

(3) Train Length and its Weight

However the question remains, as to how much actual increase in line capacity will be achieved if automatic signals are adopted in India. Hence the Study Team conducted the investigation into the parameters and performance of the various trains. The followings were the results based on that investigation.

- The length of the trains is determined by that of the loops (if the average effective loop length is 715 m, then the maximum train length is 686 m). It was realized that train length, for trains other than passenger trains, was arranged to be as close to the limit for effective loop length as possible.

  For reference, the effective length of one of the most representative line in Japan, the Tokaido line, is 585 m and the maximum train length is 550 m.

- The maximum speed is based on the restriction of braking distance within 1,200 m under emergency brake. As a result, the maximum speed for passenger trains and container trains, which have lighter train weights, is higher than the other trains as shown on Table 4-1.

Table 4-1 Train Parameters and their Performance

Train Type	Maximum Speed A	Number of Wagon (Including Brake Van) B	Length per Wagon C	Weight per Wagon C	Total Weight E=B x D (Including Locomotive)	Overall Length F=B x C	Emergency Braking Distance from Maximum Speed
Passenger Train* (See Figure 4-1)	120km	24 wagons	22.3m	50 tons with AC 40 tons without AC	1,320 t	555m	**1055 m
Container Train (See Figure 4-1)	100km	45wagons	13.7m	81.3t	3,500 t	647m	—
Wagon-Type Train (See Figure 4-1)	75km	58 wagons	10.7m	81.3t	4,836t	651m	1088 m
Other Types of Freight Trains (Using Vacuum Brakes)	65km	58 wagons	10.7m	81.3t	4,836t	651m	—

*This, as in the case of Shatabdis, excludes trains of which maximum speed has been increased by enhancing braking performance.
**21 passenger cars, on flat sections.
This table was prepared based on the results of meetings with RITES.

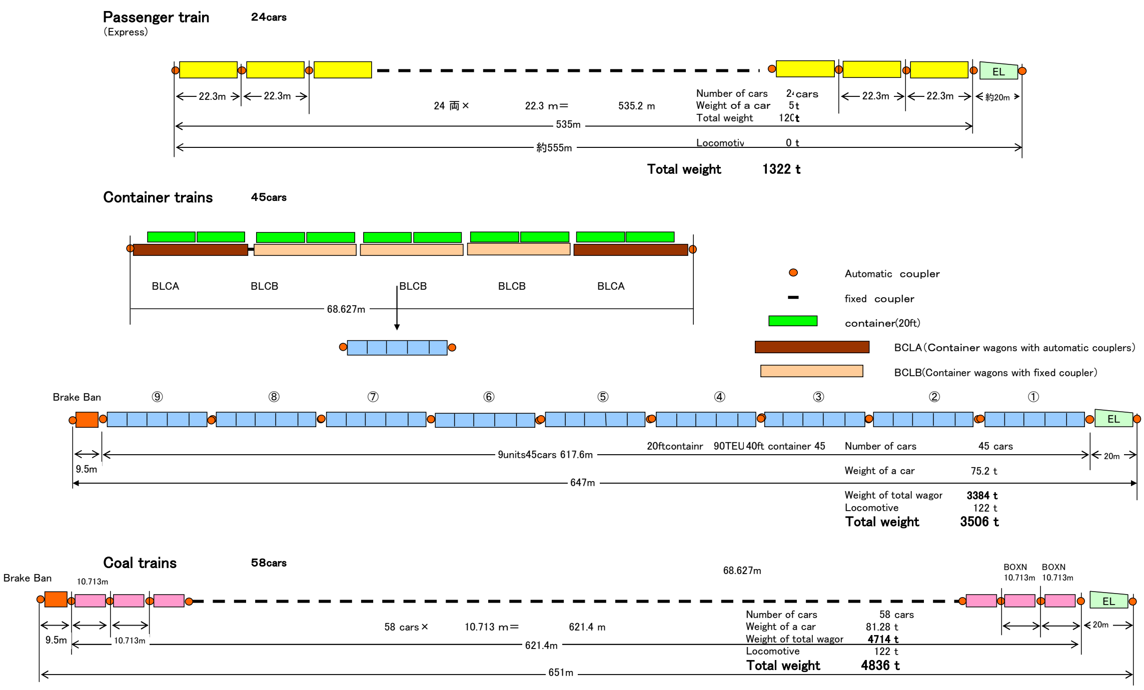


Figure 4-1 Figure of Trains

(4) Operating time between stations

In India, the operating time between stations is calculated by using the booked speed (90% of maximum speed) that has been calculated from the maximum operating speed and the distance between the relevant stations. If the train can pass through both stations, the resultant time is then used. If there are some sections that have special speed restrictions, increased operating time required due to the restriction is added.

The acceleration or deceleration time required for starting from or stopping at a station is then added to the time. (Refer to 4.1.3 for acceleration and deceleration time.)

In Japan calculations of the train operating time between stations is made based on the operating curve calculation system introduced by one of the Japanese expert at a technical seminar held in Delhi. Specifically, it is a calculation system that incorporates data about track conditions (curves, grades, speed restrictions at switches, etc.), rolling stock performance, and hauled freight car weight. India has been looking into this operating curve system, but has not actually implemented one yet.

4.1.2 Present situation of Traffic and Train Operation on the target lines

Generally speaking, the annual traffic trends for rail transport show little fluctuation. Hence, understanding the recent traffic movements is important for establishing a future plan. In this investigation, the route map of the metropolitan area was first drawn up (See Figure 4-2). Since the metropolitan area is large with complicated routes it becomes one of the major bottlenecks in the area of rail transportation.

It is pertinent to note that Indian Railways does not provide a timetable for freight trains. So the data for train operation have been obtained with the following ways.

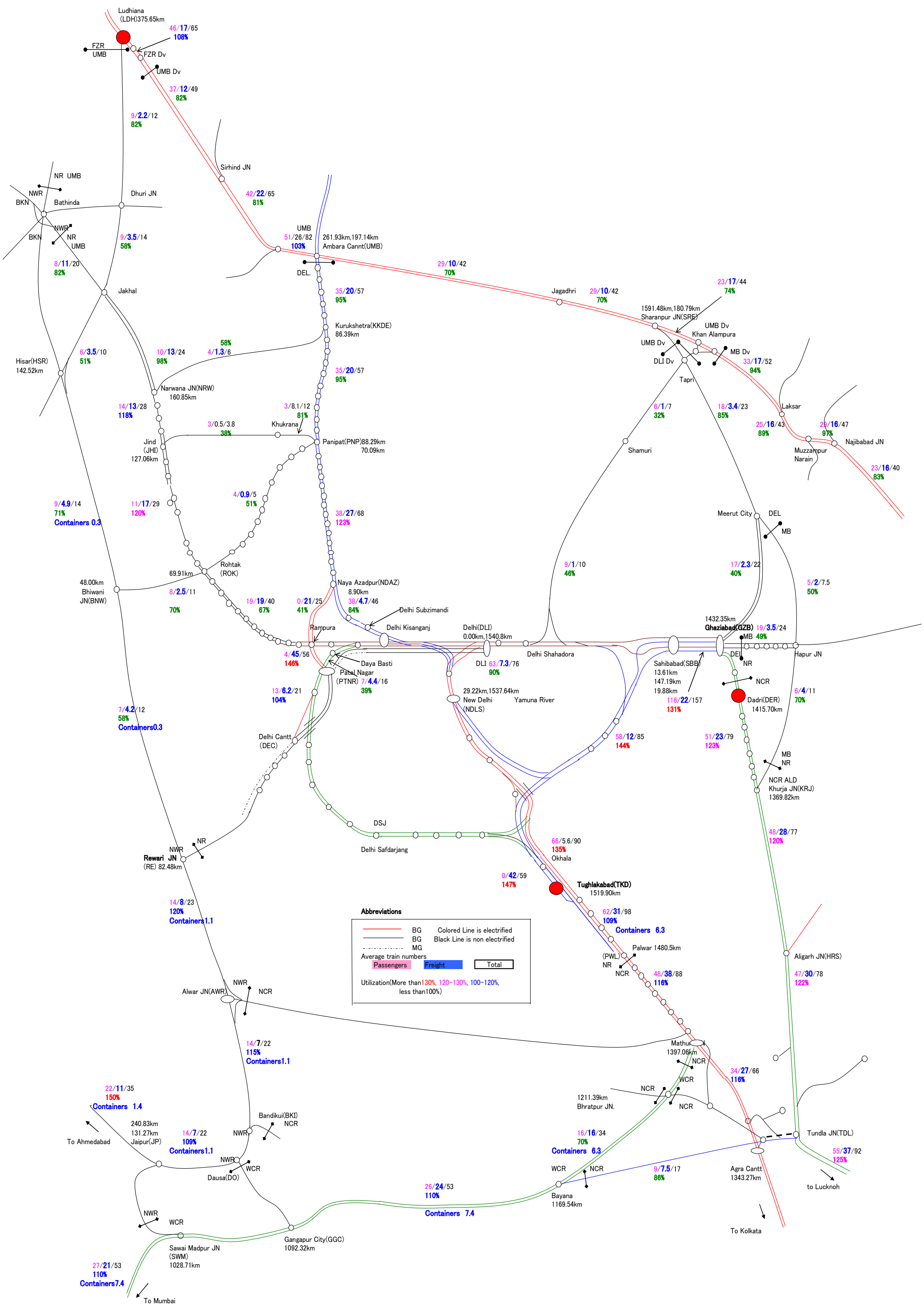
1) Number of passenger and freight trains in each section

   The train operation performance data found in the year 2004-05 line capacity statements provided by each of the Zonal Railways was condensed and arranged in the attached table (Table 4-2 to Table 4-4). In principle, the base data was collected for a six-month period from November 2004 to April 2005. The monsoon season was avoided, during which train operation gets frequently stopped.

   It may be noted that in Japan, whenever the train operation diagram is modified, a table of the train numbers for each section is created to make it available for this line capacity statement. The operating schedules for freight trains in Japan are also fixed, so it is possible to create a table of the train numbers based on the information available at the planning stage. This table only shows the number of trains by each type and it does not show the line capacity.

2) Train Diagram

   The train diagram with not only the passenger trains but also the freight trains are drawn based on the control chart that dispatchers create daily (Figure 4-3). The section from Vasai Road to Surat of the Western Railway was chosen as a trial section. On this train chart the planning chart are also drawn with dotted line and the train delay time can be obtained by comparing the actual train chart with the planned chart.



With the number of train by each section and by passenger and freight trains (based on the line capacity statement of each zonal railways2004-2005)

Figure 4-2 Route Map of the Metropolitan Area

Table 4-2 Average Sectional Train Number 2004-05 (Western Corridor-Southern Route)

Section	Distance km	Line Capacity (WOMB)	Passenger train	Freight train		Total(included trains for official use)	Utilization ratio %（WOMB)	Division and Comments (※more than 120%)
				Number	Break down of container trains			
JNPT-Jasai	9.0	12	0	10.2	10.2	11.7	97.5	CR
Jasai-Panvel	16.0	22	0	10.6	10.6	14.2	64.5	CR
Panvel-Diva	26.0	48	14.0	19.6	10.6	36.6	76.3	CR
Diva-Vasai road	42.0	48	10.0	20.1	**	32.9	68.5	CR
Vasai road-Virar	8.2	126	145.5*	16.0	**	165.5	115.5	WR-BCT
Virar-Dahanu Road	63.8	75	53.7	15.8	8.7	73.6	98.2	WR-BCT
Dahanu Road-Valsad	74.4	60	47.7	17.9	8.7	69.8	116.3	WR-BCT
Valsad-Udhna	64.4	60	48.8	18.2	8.8	70.8	118.0	WR-BCT
Udhna-Surat	4.0	70	59.7	20.8	8.8	82.7	118.2	WR-BCT
Surat-Bharuch	58.9	65	49.9	23.3	8.8	76.0	117.0	WR-BRC
Bharuch-Vadodara(P)	70.1	65	49.4	23.5	8.8	76.3	117.4	WR-BRC
Vadodara(P)-(D)	4.6	85	70.4	23.8	8.6	108.4	**127.5**	WR-BRC※
Vadodara(D)-(Z)	2.1	55	25.8	12.5	6.6	40.1	72.9	WR-BRC
Vadodara（Z）-Godhra	67.0	55	25.8	19.1	6.8	47.7	86.8	WR-BRC
Godhra-Ratlam	185.2	55	25.4	26.8	7.1	57.8	105.1	WR-RTM
Ratlam-Nagda	41.4	55	26.4	28.3	7.6	58.4	106.1	WR-RTM
Nagda-Kota	225.0	48	23.0	19.6	*7.4*	45.8	95.3	WCR-KOTA
Kota-Gurla	5.6	48	30.0	26.3	*7.4*	66.1	**137.8**	WCR-KOTA※
Gurla-Sawai Madopur	102.2	48	27.0	21.2	*7.4*	52.7	109.9	WCR-KOTA
Sawai Madopur-Bayana	140.8	48	26.0	23.9	*7.4*	52.8	110.0	WCR-KOTA
Bayana-Mathura	75.41	48	16.0	16.3	*6.3*	33.5	69.8	WCR-KOTA
Mathura-Palwal	83.4	76	48.0	37.7	*6.3*	88.4	116.3	NCR-AGC
Palwal-Tuglakabad	39.4	90	62.0	31.2	*6.3*	98.4	109.3	NR-DLI

- Based on Line Capacity Statements 2004-05 of each Zonal Railway
- The data written in Italic figures are from the RITES Report (2003-04)
- Abbreviations: WOMB(Without Maintenance Block), CR(Central Railway), WR(Western Railway), BCT(Mumbai Division), BRC(Vadodara Division), RMT(Ratlam Division), WCR(West Central Railway), KOTA(Kota Division), NCR(North Central Railway), AGC(Agra Division),NR(Northern Railway), DLI(Delhi Division)

* EMU for suburban transport is included

** Is not shown in the line capacity statement

Table 4-3 Average Sectional Train Number 2004-05 (Western Corridor-Northern Route)

Section	Distance km	Line Capacity (WOMB)	Passenger train	Freight train		Total(included trains for official use)	Utilization ratio % (WOMB)	Division and Comments (more than 120%)
				Number	Break down of container trains			
Vadodara(D)-Bajva	2.7	63	46.1	11.3	2.0	64.3	102.0	WR-BRC
Bajva-Vasad	13.0	63	46.1	14.2	2.2	63.8	101.2	WR-BRC
Vasad-Anand	15.5	63	44.1	12.9	2.2	60.4	95.9	WR-BRC
Anand-Kanjari Boriyavi	7.5	70	49.1	17.1	2.5	69.5	99.3	WR-BRC
Kanjari Boriyavi - Geratpur	52.2	70	47.1	17.1	2.5	67.6	96.5	BRC-ADI
Geratpur-Vatva	3.3	70	46.7	17.0	2.1	73.2	104.5	WR-ADI
Vatva-Kankaria	6.1	70	46.7	17.4	2.1	73.9	105.5	WR-ADI
Kankaria-Ahmedabad	1.8	72	46.7	19.4	2.9	99.9	**138.7**	WR-ADI*
Ahmedabad-Sabarmati	5.4	63	40.6	19.4	2.9	69.5	110.3	WR-ADI
Sabarmati-Chandlodia	5.7	65	40.6	18.7	0.4	63.8	98.2	WR-ADI
Chandlodia-Khodiyar	9.3	24	18.3	5.9	0.9	26.2	109.3	WR-ADI
Khodiyar-Mahesana	52.6	24	17.3	3.0	0.9	20.5	85.5	WR-ADI
Mahesana-Palanpur	65.1	24	17.3	7.8	2.9	25.3	105.3	WR-ADI
Palanpur-Abu Road	52.6	22	18.0	7.5	2.6	25.7	117.0	NWR-AII
Abu Road-Marwar Jn	165.2	20	17.0	8.2	2.6	27.1	**136.0**	NWR-AII
Marwar Jn-Beawar	87.7	20	12.0	6.6	2.2	19.6	98.0	NWR-AII
Beawar-Daurai	45.1	22	13.0	6.8	2.2	21.3	97.0	NWR-AII
Daurai-Madar	13.3	20	0	6.7	2.2	7.8	38.8	Ajmer detoured
Madar-Phulera	73.3	20	13	7.2	1.1	20.9	104.5	NWR-JP
Phulera-Jaipur	54.3	23	22.0	11.2	1.4	34.6	**150.4**	NWR-JP※
Jaipur-Bandikui	90.3	20	14	6.7	1.1	21.7	108.5	NWR-JP
Bandikui-Alwar	60.4	21	14	7.0	1.1	21.8	103.8	NWR-JP
Alwar-Rewari	74.2	22	14	8.3	1.1	23.3	105.9	NWR-JP
Rewari-Delhi	82.5	24	15	6.5	-	22.7	94.6	NR-DLI

- Based on Line Capacity Statements 2004-05of each Zonal Railway
- Abbreviations:WR(Western Railway),BCT(Mumbai Division), BRC(Vadodara Division),ADI(Ahmedabad Division), NWR(North Western Railway), AII(Ajimer Division), JP(Jaipur Division), NR(Northern Railway), DLI(Delhi Division)

Table 4-4 Average Sectional Train Number2004-05 (Eastern Corridor)

Section	Distance km	Line Capacity (WOMB)	Passenger train	Freight train	Total (included trains for official use)	Utilization ratio %(WOMB)	Division and Comments
Howrah-Belur	6.6	207	180.0*	6.0	188.5	91.1	ER-HWH
Belur-Dankuni	8.2	72	50.0	6.0	57.5	79.9	ER-HWH
Dankuni-Gurap	42.7	79	59.0	18.0	78.5	99.4	ER-HWH
Gurap-Saktigarh	25.4	74	52.0	18.0	71.5	96.6	ER-HWH
Saktigarh-Barddhaman	11.5	125	94.0	26.0	122.5	98.0	ER-HWH
Barddhaman-Khana	13.2	130	66.0	28.0	96.0	73.8	ER-HWH
Khana-Andal	66.5	112	50.0	24.6	91.9	82.1	ER-ASN
Andal-Asansol	25.7	116	50.0	29.8	94.5	81.5	ER-ASN
Asansol-Sitarampur	8.9	118	48.0	23.2	82.5	69.9	ER-ASN
Sitarampur-Chotaambona	34.4	83	26.0	21.0	58.8	70.8	ER-ASN
Chotaambona-Pradhankhanta	5.6	81	26.0	21.0	51.8	64.0	ER-ECR
Pradhankhanta-Dhanbad	9.6	73	33.0	16.5	50.3	68.9	ECR-DHN
Dhanbad-Gomoh	29.3	74	20.0	21.2	42.4	57.3	ECR-DHN
Gomoh-Gaya	169.2	53	20.0	23.5	43.8	82.6	ECR-DHN
Gaya-Sonnagar	79.4	66	22.0	26.4	52.4	79.4	ECR-MGS
Sonnagar-Dehri-on-sone	5.8	77	25.0	45.2	74.2	96.4	ECR-MGS
Dehri-on-sone-Mughal Sarai	117.2	80	21.0	45.2	69.2	86.5	ECR-MGS
Mughal Sarai-Jeonathpur	7.8	64	37.0	34.9	72.4	113.1	NCR-ALD
Jeonathpur-Chunar	24.4	64	38.0	36.6	75.2	117.5	NCR-ALD
Chunar-Mirzapur	31.0	66	42.0	37.2	79.8	**120.9**	NCR-ALD※
Mirzapur-Cheoki West	80.8	66	42.0	37.3	79.9	**121.1**	NCR-ALD
Cheoki West-Naini	1.4	64	37.0	31.5	69.1	108.0	NCR-ALD
Naini-Allahabad	7.5	80	52.0	32.9	86.4	108.0	NCR-ALD
Allahabad-Bamrauli	9.0	70	37.0	34.2	73.8	105.4	NCR-ALD
Bamrauli-Fatehpur	107.7	63	37.0	34.2	71.8	114.0	NCR-ALD
Fatehpur-Chandari	73.6	64	38.0	34.8	73.4	114.7	NCR-ALD
Chandari-Kanpur(CNB)	3.9	53	38.0	0	38.0	71.7	Passenger train only
Chandari-GMC	2.0	43	0	34.9	35.5	82.6	Detoured line
Kanpur(CNB)-Juhiwest	1.4	79	68.0	42.1	110.7	**140.1**	NCR-ALD※
Juhiwest-Panki	7.4	66	55.0	35.9	91.5	**138.6**	NCR-ALD※
Panki-Shikohabad	183.5	66	55.0	35.9	91.5	**138.6**	NCR-ALD※
Shikohabad-Tundla	36.6	66	55.0	36.6	92.2	**139.7**	NCR-ALD※
Tundla-Tundlawest	1.2	80	59.0	38.7	99.7	**124.6**	NCR-ALD※
Tundlawest-Barhan	14.7	64	48.0	30.4	79.0	**123.4**	NCR-ALD※
Barhan-Aligarh	68.3	64	47.0	30.2	77.8	**121.6**	NCR-ALD※
Aligarh-Khurja	43.3	64	48.0	28.0	76.6	119.7	NCR-ALD
Khurja-Dankaur	28.2	64	49.0	27.2	76.8	**120.0**	NCR-ALD※
Dankaur-Dadri	17.7	64	51.0	27.2	78.8	**123.1**	NCR-ALD※
Dadri-Ghaziabad	16.7	64	51.0	23.4	76.0	118.8	ALD-DLI

- Based on Line Capacity Statements 2004-05of each Zonal Railway
- Abbreviations: ER(Eastern Railway), HWH(Howrah Division), ASN(Asansol Division), ECR(East Central Railway),DHN(Dhanbad Division), MGS (Mughal Sarai Division), NCR(NorthCentral Railway), ALD(Allahabad Division), NR(Northern Railway), DLI(Delhi Division)

*EMU for suburban transport is included

It is easy to see by looking at these tables that the number of trains for each section of each track segment concurs with the logistical movements shown in the reports by the JICA preliminary investigation groups and the RITES Report. The details are shown below.

Eastern corridor

- Near Howrah and Bardhaman there are many trains that appear to be commuter trains. The number of trains here exceeds 100. These sections have four lines, which is why the number of trains is high.
- In the area of passenger trains, there are basically 40 trains in operation (with the exception of the section from Asansol to Mughal Sarai which has parallel routes). In particular, the section from Kanpur to Delhi has more than 55 passenger trains operating on it.
- In the area of freight trains, the section extending north from Dankuni has more than 20 trains per direction operating on it. And the route west of Sonnagar has a base of more than 30 trains. This is due to the transport of commodities such as coal and iron ore from the Sonnagar region in the east to the Ludhiana region in the north.

Western corridor

- Number of passenger trains per day per direction is about 20 trains though there are trains that enter and exit between Mumbai and Delhi. On the section from Vasai Road to Vadodara, there are many routes that go in all directions around Mumbai and the number of trains is increased to forty or fifty in this section. On the section from Mathura to Delhi, urban commuter rail traffic also gets added, increasing the number of trains to 40 or 60. A similar increase of the number of trains can be seen even in the area around Kota.
- The section from JNPT to Panvel is a dedicated freight track and it is only be used for container trains. The double-track construction for this section was completed in August 2006.
- Container trains already comprise about 30 to 40% of the freight train traffic. There are 9 to 10 trains that head from Mumbai to Delhi, but since some of these trains go to Ahmedabad and Vadodara, there are only 7 trains running to the north of Vadodara. After that, at Bayana, one train goes toward Agra while the remainder appears to go to Tuglakabad.
- Common freight trains enter on the routes going north from Surat. This pushes the number of freight trains up into the mid twenties. The flow of this traffic extends mainly to the Kota area.

Western route (Northern course)

- The number of both passenger and freight trains operating drops in half to the north of Chandlodia.
- Container freight trains from Mumbai come into this route at Ahmedabad.

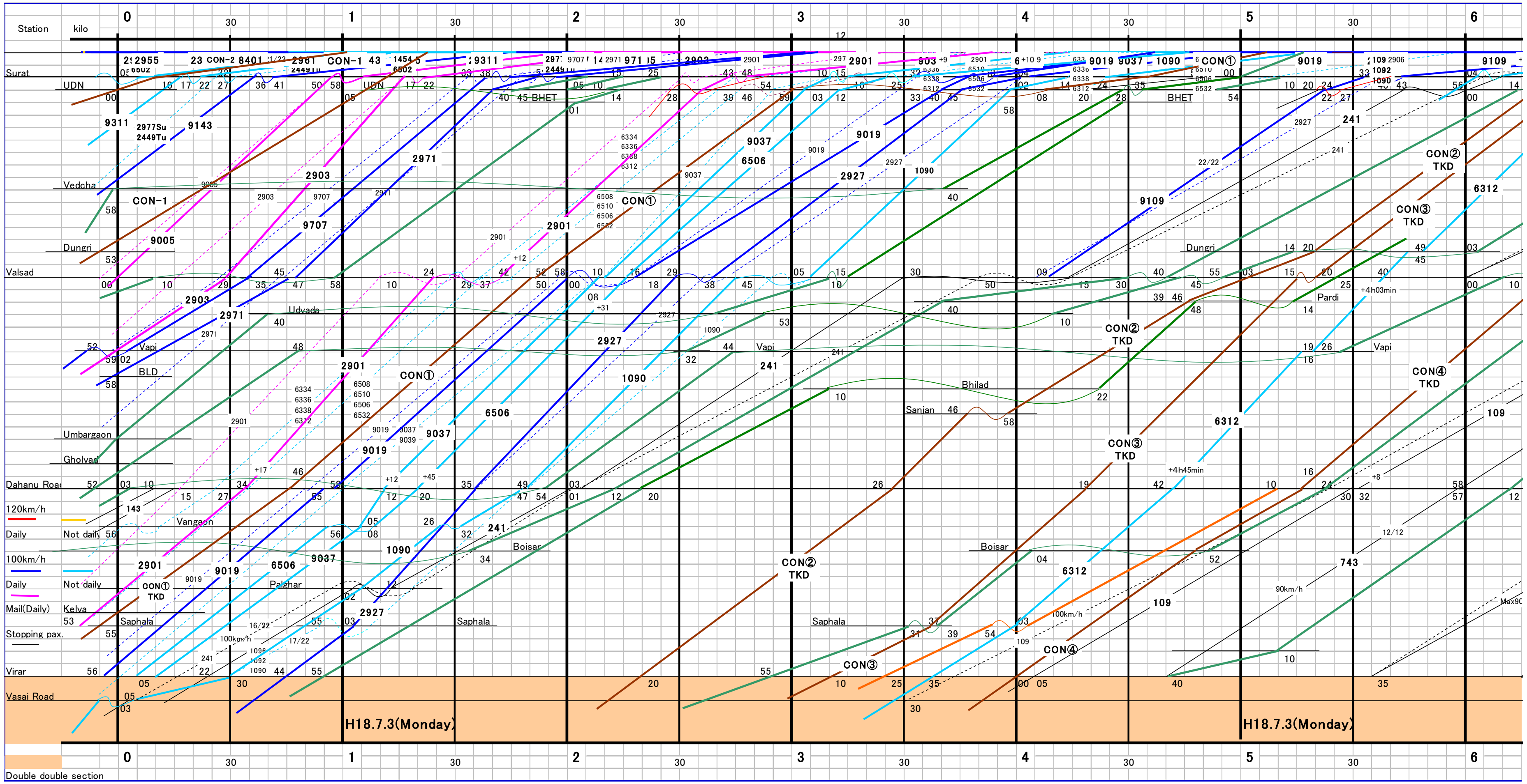


Figure 4-3 Train Diagram (1/4)

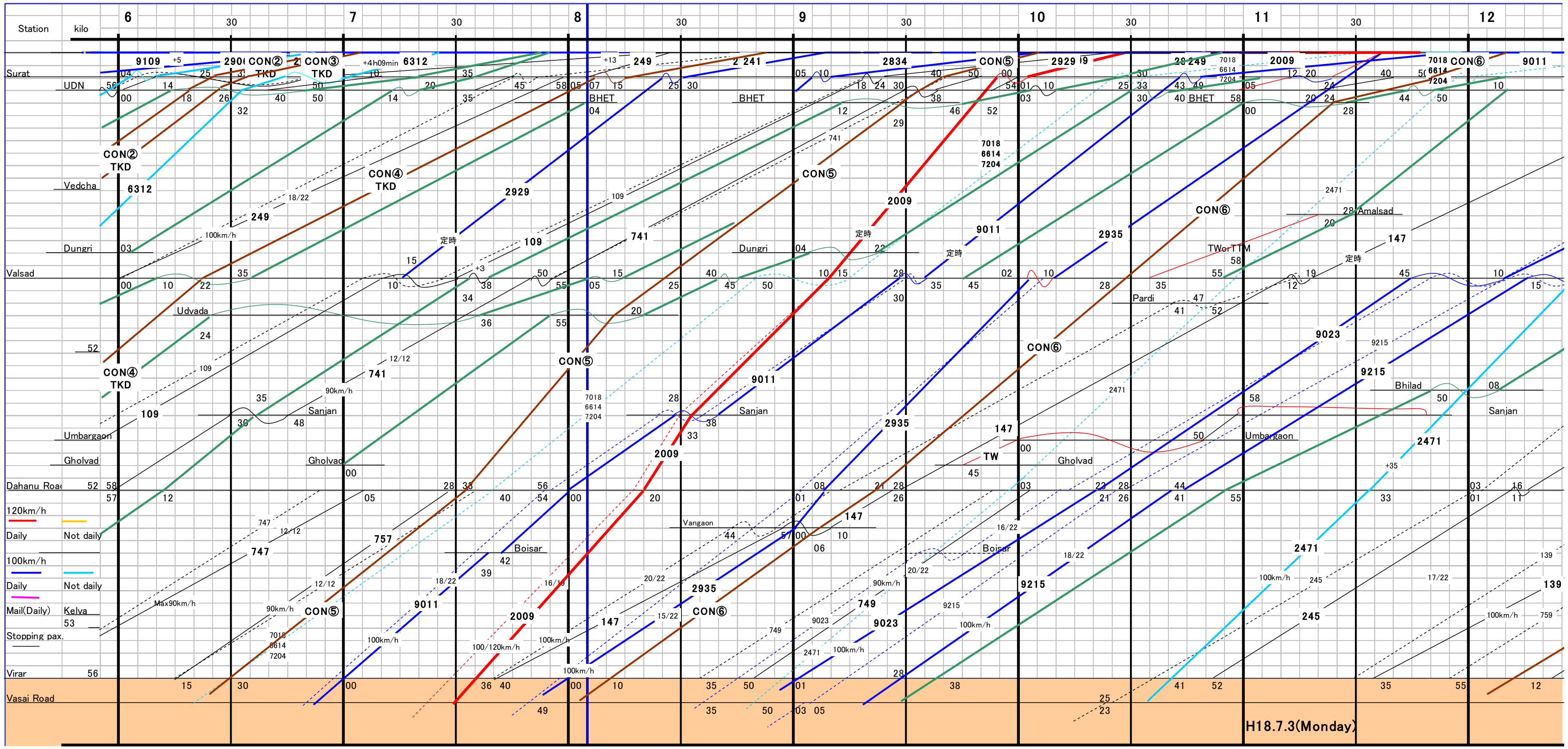


Figure 4-3 Train Diagram (2/4)

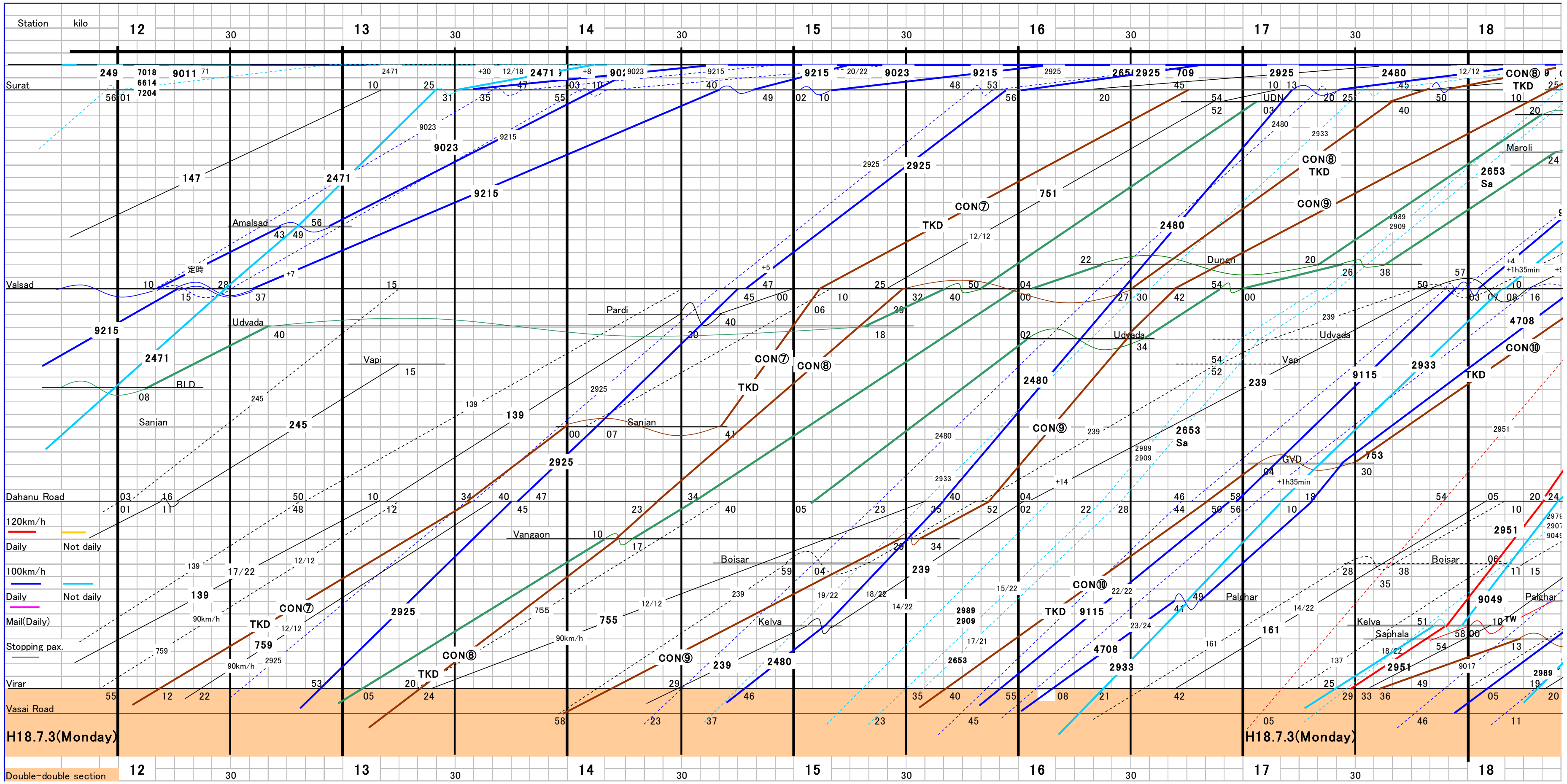


Figure 4-3 Train Diagram (3/4)

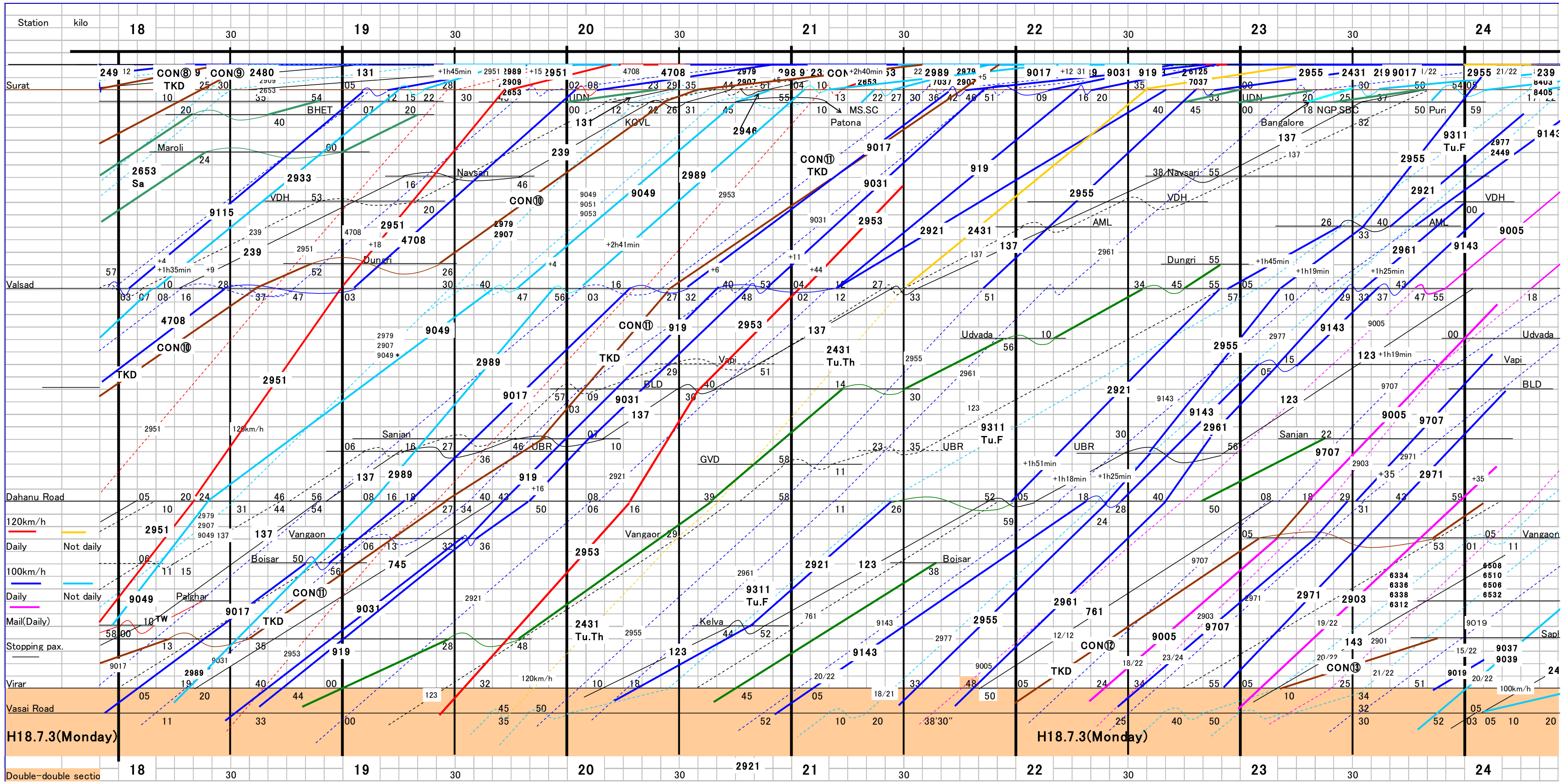


Figure 4-3 Train Diagram (4/4)

4.1.3 Bottlenecks in Transport

Even if a line is composed of sections with various traffic capacity and some of them have exceptionally higher capacity than other sections, sections having the least traffic capacity become the bottleneck for the entire line. In order to increase the traffic capacity of the entire line, the traffic situation of those sections with limited capacity needs to be examined one by one to clarify the reason causing such limited traffic.

Generally speaking, near the station, where the behaviour of trains is fairly complicated. Bottlenecks also commonly occur at areas between stations, at such places, where there are steep gradients or sharp curves that cause trains to reduce its speed. Bottlenecks may also occur due to configuration of signalling system.

The following section summarises the fundamental cause of bottlenecks identified by the Study Team. There are two categories of reasons, one found between stations and the other found within stations. The information presented are the results compiled, based on discussions with officers in charge of traffic in MOR, Zonal Railways, RITES and analysis of practises in Japan.

(1) Bottlenecks between Stations

Most intercity double-track railway lines of Indian Railways allow only a single train to operate between stations. Because of this operational restriction, the section between two stations becomes the bottleneck.

The following are elements that determine the line capacity between stations.

[Restrictions due to signalling equipment]

Even though the intercity lines of Indian Railways are with double-track arrangement, only a single train can operate between two consecutive stations. This is due to the configuration of the signalling system for that section. One way of improving the line capacity is by installing intermediate block system within the section. This arrangement would allow two trains to operate between consecutive stations.

[Restrictions due to train booking speed]

The Indian Railways prepares the train diagram based on the operating time between stations that is calculated based on the length between the stations and the booking speed, which is assessed at 90% of the maximum speed of the train. In practice, operation at the maximum speed is allowed when the train falls behind schedule. Operating procedures call for restricted maximum speeds in sections with grades. This reduces the number of trains that can be operated. In India, there are few sections that have restrictions due to gradient. Only a limited number of sections with maximum speed restrictions due to sharp curves have been found in the working time table.

[Reductions in the average speed and number of trains that can be operated due to stopping of trains]

Empirical data shows that when a passenger or freight train at halt (with a maximum speed of 75 km) starts, two more minutes are needed for taking the train to reach the booked speed. And three more minutes are needed for its stopping. These figures vary and becomes much larger than the time allocated, depending upon the performance of the rolling stock.

As a result, the average speed of passenger train that stops at every station becomes lower than the booked speed of a train that passes through every station. And, the average speed of a freight train that must be pulled off from the main track to allow a passenger train to pass will be much lower than the booked speed.

These factors increase the operating time between stations and reduce the number of trains that can be operated.

[Effect of operation of trains with different speeds upon the number of trains]

If trains with different speeds are operated in one section, the faster train will overtake the slower train at a station along the way. This means that the slower train will have to wait at a station for the faster train to pass. As a result, time for acceleration and deceleration of the slower train will have to be taken into account in the operating time between stations. And the operating time between stations for the slower train will become even longer. This will reduce the number of trains that can be operated in that section.

(2) Constraints in the Stations

Currently the Indian Railway's signalling system equipped between stations allows only one train to operate at one time. Because of this restriction, the areas in the station and near it are not the factors that restrict the number of trains that can be operated in the planning stages. However, several cases have been observed during the actual operation of the train where this has caused train delays or becoming a factor in increasing delays. The RITES Report also points out this as reason for causing bottlenecks.

If the loops of the stations are occupied by the trains, the trains operating behind cannot enter these stations. Having trains queue at the home signals slows the operation of following trains even more. This reduces the number of trains that can be operated, and impedes smooth transport.

The following Figure 4-4 depicts three cases where trains occupying the loops in the station affect the operation of the following trains.

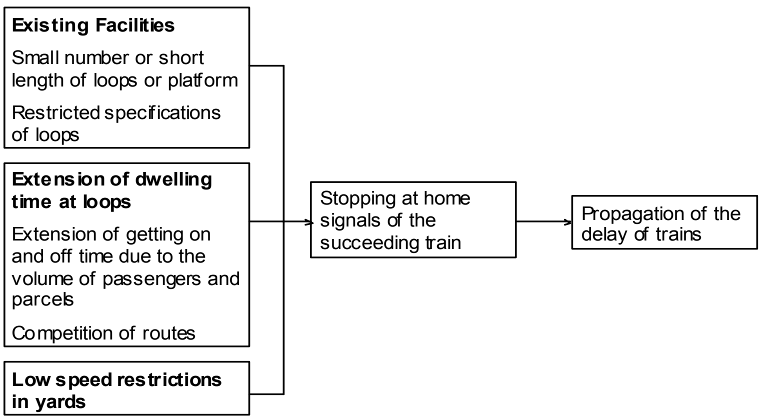


Figure 4-4 Causes of Stopping of Succeeding Trains at Home Signals

[Restrictions due to station facilities]

The most common cause of operational constraints is due to configuration of station facilities, such as the platforms. If trains are not operating on schedule and are queued at the station, the loops for other trains to enter are blocked and the following trains have to stop at the home signal and wait. An observation made by the Study Team concluded that the length of the platforms for some of the loops are insufficient, so there is a tendency to use the longer platforms for handling passenger trains. Because of this, the platform becomes crowded with passengers waiting for a train, causing delays in the boarding and alighting from the train. This phenomenon was observed at Vadodara Station.

There are other reasons that can cause the extension of passenger train stoppage time. These may include instances when there is a need to switch locomotives at a station to accommodate changes in electrified and non-electrified sections, or for instance when there is a need to change the position of the locomotive to accommodate a change in the direction of travel and when the station has been designated as a place for changing crews.

[Incidental cases]

The second most common cause of operational constraints is incidental events during daily operations. Since the operation of freight trains on the Indian Railways is not according to a schedule, the incidental stopping of freight trains extends the time at the stations. There are other cases such as the time required for the boarding and alighting of an unusually large number of passengers, additional time required for loading and unloading baggage or freight, or even a departure that was delayed because the track ahead was occupied by another train. The latter case is presented below.

On double track sections, trains on one set of tracks all travel in the same direction. Because of this, if the sequence of the trains is regulated by an operating commands based on a train diagram or other protocol, it is possible to regulate the interrelationship one train will have with those following it. However, if the trains operate on different tracks, this inter-relationship cannot be regulated. Stations have many places where different tracks cross each other. At these locations, even if the operating order of the trains is regulated by a plan, if one train is late, it is impossible to make provisions until one of the trains passes through. As a result, these locations have a high potential for propagating train delays. The main pattern for this is as shown in the Figure 4-5. There are two cases, in one instance wherein two tracks merge into a line and the other instance where one track crosses multiple tracks.

In order to eliminate such bottleneck locations, Indian Railways is removing these crossing locations through such means as providing detour routes, avoiding such merging, providing flyovers and eliminating intersections with other tracks. The Study Team observed good examples of these measures during site visits and were able to see a detour route in New Delhi Station for freight trains to avoid other freight and passenger trains, as well as a flyover at Mughal Sarai.

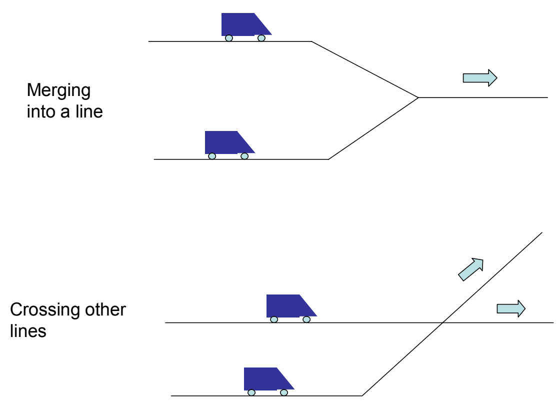


Figure 4-5 Operational Constrains by Merging or Crossing at Stations

Figure 4-6 elaborates on the examples found in Figure 4-5 in which trains bound in different directions have a conflict.

Figure 4-6 summarizes the routes in the yard at Surat Station. This station also has a goods yard on one side of the station yard. The common loop is on the goods yard side of the station. In automatic double line the direction of the lines are normally fixed though trains can run in both directions in ABS mode. With this route alignment, a down train must cross the up main track when taking refuge on a common loop. This causes a route conflict for both down and up trains. Many of the down trains have to wait for long time at the outside of the home signal. The Study Team investigated the line capacity on the preconditions that these route conflicts among up and down trains are eliminated.

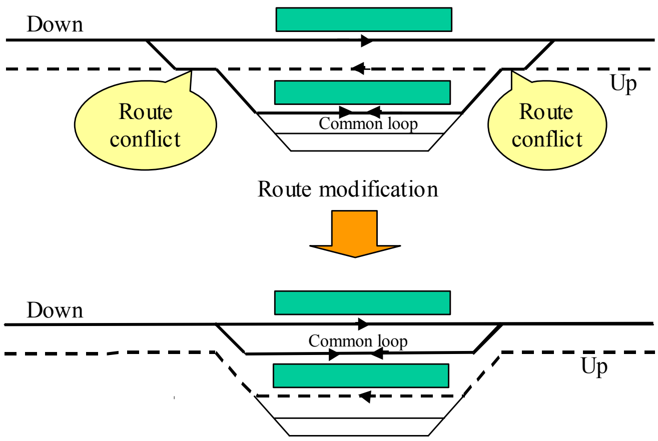


Figure 4-6 Route Conflict for Up and Down Tracks and its Resolution

[Low in-yard transfer speed]

The third common cause of operational constraints is the low speed at which trains stopping at a station move through stations. Because the speed limit for trailing speed over a turnout is limited to 15 km/h, the operating speed throughout the entire station premise is dictated at a slower speed. As a result, it would have the same effect as the train retention time in a loop.

(3) Identification of Bottleneck Sections by Comparison of Actual Line Capacities

When the number of the trains of the line capacity and the actual train number are compared, it reveals the areas that are currently restricting traffic. Figure 4-7 to Figure 4-9 present the restricted situation of the traffic capacity between Dadri and Kanakpur on the Western route; near Kota, between Dahanu Road and Vadodara, Ratlam and Nagda, and Mathura and Tuglakabad on the Eastern route.

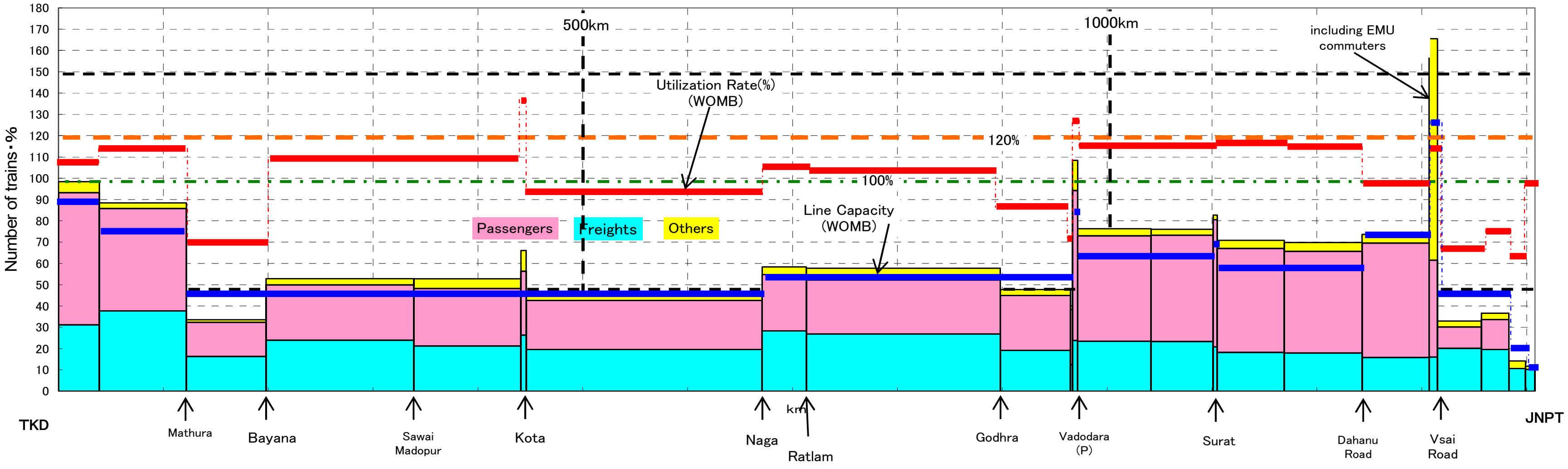


Figure 4-7 Line Capacity and the Average Number of Trains (West Corridor via Southern Route)

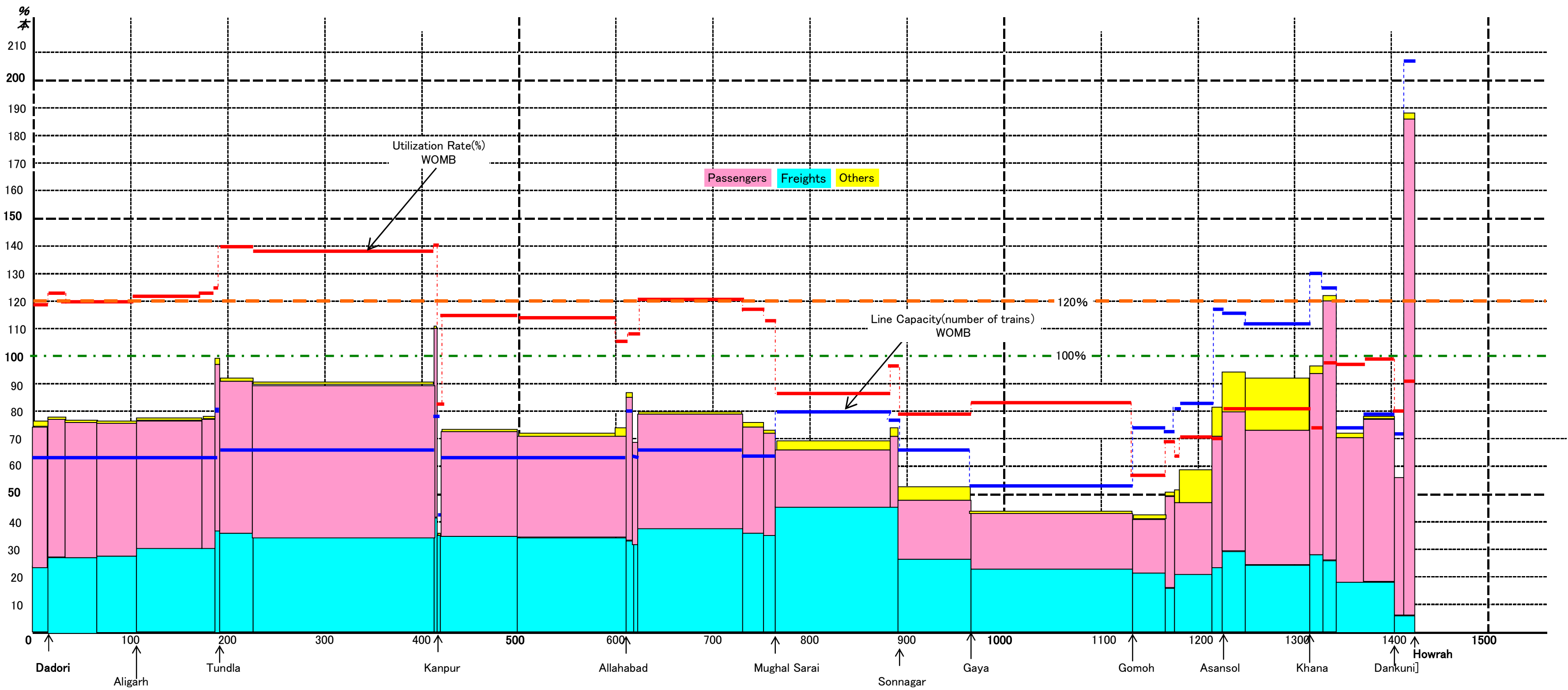


Figure 4-8 Line Capacity and the Average Number of Trains (Eastern Corridor)

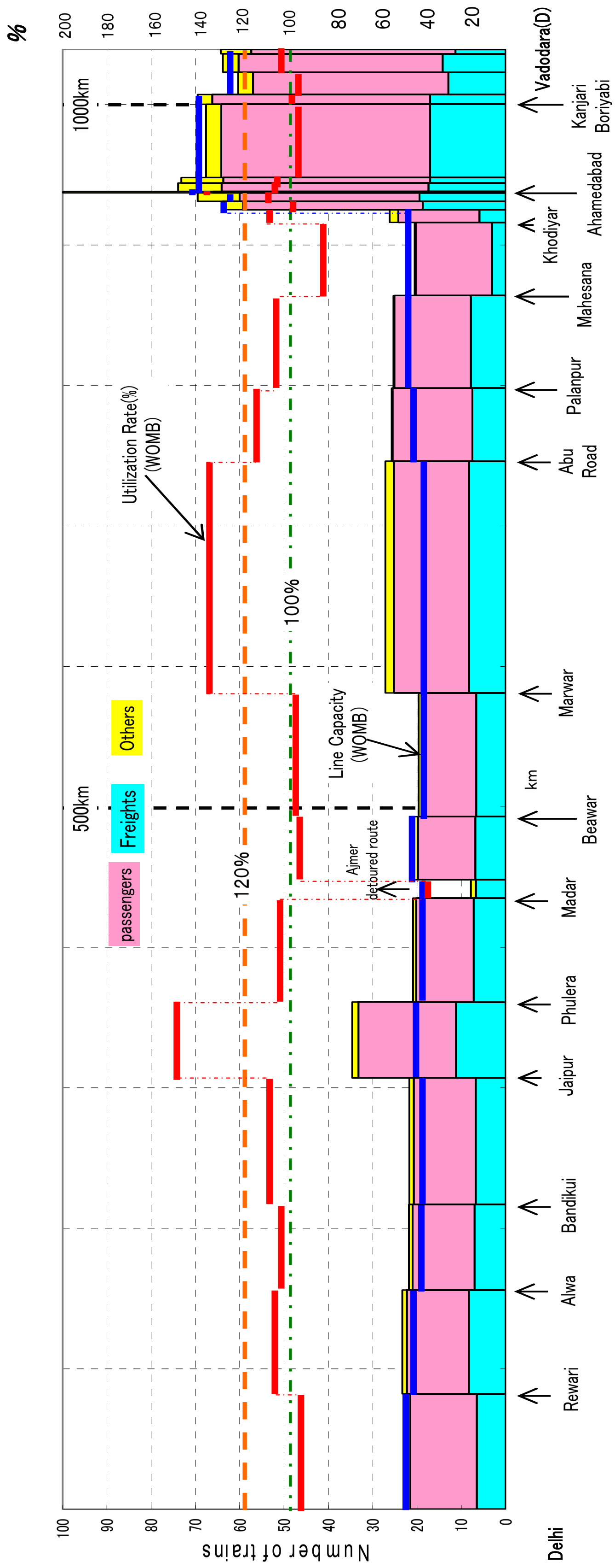


Figure 4-9 Line Capacity and the Average Number of Trains (West Corridor via Northern Route)

4.1.4 Freight Train Diagrams and Traffic Control

(1) Freight trains without time table

No fixed schedules are made for freight trains in Indian Railways. In principle, once a freight train is loaded and ready to depart, it is operated during an interval in passenger train operation.

A major demerit of operating without a freight train schedule is that the date and time of arrival cannot be specified in advance.

(2) Organising schedules giving higher priority to freight trains

The Study Team has observed that on Indian Railway, a freight train never passes a passenger train on Indian Railways. The only exception is when a freight train passes a passenger train that is stopping at every station.

It is not uncommon for a freight train to be pulled off the main track at a station along the way, to allow a passenger train to pass. Freight trains have lower maximum speeds than passenger trains. Passenger trains have train schedules. This means that in order to maintain the schedule, the passenger train must overtake the slower freight operating ahead of it.

The punctual operation of the freight trains cannot be maintained due to this priority given to passenger trains.

It seems that when the freight trains are given the same priority as passenger trains, traffic control will be carried out from the standpoint of minimizing overall delay. When this occurs, delay causes such as the incidental refuge of freight trains to a loop to allow passenger trains pass will be drastically reduced.

(3) Freight Train Operation System with time table

Freight trains in India do not have a time schedule. The main reason behind it is that, perhaps Indian Railways assumes that there is no reason to operate a freight train if there is no freight to transport and if a station that normally does not have freight suddenly needs to ship freight, a train can be quickly arranged to do it. It is felt however, that it is still possible to respond in this manner, even if a train timetable is established for freight trains.

In Japan, all freight trains have operating schedules. Based on the experience in Japan to have a schedule for freight trains offers the following four merits.

1) It clarifies the arrival time of all trains.
2) It improves the utilization efficiency of the locomotives and crews.
3) It improves safety by providing advance notification of the operating schedule to track maintenance crews and level crossing attendants. (In practice, the intervals during which major maintenance can be carried out, is made clear in advance in India.)
4) Train delays causing problems in train operation can be identified and corrected based on this information. (Train delay suggests that there are some problems against normal train operation)

A master chart is created for counting the charted line capacities. The schedule for freight train operation is included in the master chart. On some Divisional Railways, train numbers and schedules for high-speed freight trains, such as container trains are fixed. In addition, at Tuglakabad, container trains arrive at approximately the same time every day. It is envisioned that the time will come when operating schedules for freight trains will have to be created for the entire Indian Railways system.

4.2 STATIONS / YARDS

4.2.1 Role of stations/yards on existing trunk lines for freight traffic

The corridors of Delhi to Mumbai and Delhi to Howrah, Ludhiana to Khurja, include the most important routes for freight and passenger traffic on Indian Railways. Here two trunk lines pass through: Delhi-Mumbai Main Line (Delhi-Mathura-Kota-Vadodara-Vasai Rd.-Mumbai: 1,541 km) and Delhi-Howrah Main Line (Delhi-Tundla-Kanpur-Allahabad-Mughal Sarai-Sonnagar-Asansol-Howrah: 1,462 km). The traffic capacity on these trunk lines is being strained by the dramatic increase of volume of railway traffic brought on by remarkable economic growth of India.

This is particular in freight transport. Freight trains are being operated at the length of rakes close to the limit, which is the Indian Railways' standard effective length of track (CSR), i.e. 686 m, and has no other way to accommodate the traffic demand other than to increase the operating number of trains.

Demand for passenger service, particularly demand for long-distance express trains that link major cities, has also increased to the point that it is difficult to get a reserved seat.

A careful examination of the current conditions of stations/yards that play an important role in the functioning of these trunk lines is undertaken, in order to identify the problems that are depleting the line capacity and the measures to be undertaken.

On these sections of lines there are various types of stations/yards. For the purpose of this study, they have been classified as follows: 1) large scale multifunction stations/yards, 2) marshalling yards, 3) medium scale stations/yards, 4) intermediate stations (with loops), 5) intermediate stations (without loops). (Note that these classifications are not the official classifications used by Indian Railways, but rather are classifications devised by the Study Team based on the actual function and scale of these facilities.).

4.2.2 Large-scale multifunction station/yards

Large-scale multifunction stations/yards are located in major cities and where trunk lines converge. Generally speaking, Indian Railways does not use separate stations for passenger and freight services. Nearly all of the major stations have large-scale multifunction stations/yards that include a combination of facilities such as the following: passenger station, freight station (loading/unloading sidings, including private sidings/lead-in tracks), locomotive depot, passenger car depot and freight wagon depot.

The location of these large-scale multifunction stations/yards is as follows. On the Delhi-Mumbai Main Line on the Western Corridor, they can be found at Delhi, New Delhi, Tuglakabad, Mathura, Kota, Ratlam, Vadodara, Mumbai Central and other stations. On the Delhi-Howrah Main Line on the Eastern Corridor they can be found at Delhi, Ghaziabad, Tundla, Kanpur, Allahabad, Mughal Sarai, Andal, Howrah and other locations. And there are several large-scale multifunction stations/yards on the northern route of the Western Corridor, such as at Ahmedabad and Sabarmati.

These large-scale multifunction stations/yards as well as the marshalling yards feature a long, vast yard with numerous turnouts that connect the tracks to the various facilities. The most common design is to have a passenger station section and a freight station section located in a long, linear configuration. Because of this, there are many cases where the combination of the speed restrictions at the turnouts and the speed restrictions for design or maintenance reasons causes the overall speed in these locations to be 15 km/hr (some places it is even 10 km/hr), forcing trains to take a long time to pass through a station, delaying the arrival time of both freight and passenger trains and thereby reducing the line capacity. (More about the issue of speed restrictions at turnouts is presented later.) An example of this is the Allahabad station on the Eastern Corridor. It has a yard length of approximately 2.4 km and it takes 12 minutes for a 650 m freight train to pass through at a speed of 15 km/hr.

In addition interference due to level crossings caused by such as branching and leading into/out of reception/departure tracks etc. also reduces line capacity. The Indian Railways has many branch lines directly connected to these stations by level crossings. There are locations where the trunk lines are branched by grade separation, such as the one at Mughal Sarai, but such facilities are still rare.

Accordingly, the main issues faced by these large-scale multifunction stations/yards are the time required for passing through them and the interference due to the level crossings. Improving these issues will help to shorten travel time and increase line capacity.

Since these stations are quite large, it is not economically feasible to make radical improvements to them. Therefore, it is desirable that improvements be made to increase the efficiency effectively concerning the above issues. Compared to the time when these facilities were built, there have been many changes to the transport structure, such as those shown below.

- All freight transport is now done by unit trains. This makes it unnecessary for trains to stop and they can simply pass through stations except for occasions such as: when on the reception/departure track of the forwarding station and the receiving station, taking refuge, waiting for the clearance of the main track, changing locomotive(s), changing crews and for car examinations (when such examination has been planned for a mid-way station).
- As the unit train method is used, there is no coupling/uncoupling of a part of the train at an intermediate station.
- Passenger service has become mainly medium and long distance express trains linking major cities and commuter service in the large city areas. Transportation to local destinations has been taken over by automobiles and the role of railways for this service will be reduced.

It is therefore desirable to make improvements to meet these conditions. Improvements are mainly removal of disused items and replacing devices by better ones. Major restructuring has been avoided as much as possible.

- The role of each of the current stations/yards has to be re-examined so that unnecessary tracks can be eliminated, thereby reducing the number of turnouts.
- Routes that are not frequently used and those that can be re-routed should be eliminated, thereby reducing the number of turnouts.
- Double slip switches (DSS) that require cumbersome maintenance, on main tracks, should be eliminated as much as possible.
- The use of 1/8.5 turnouts which are on main tracks and auxiliary main tracks should be eliminated.
- It would be ideal if the level crossings at branch lines could be eliminated by converting them into grade-separated crossings. However, if this cannot be done, the tracks should be arranged so that there is no simultaneous interference to main tracks for both traffic directions. This can be accomplished by installing a loop between both the main tracks.

Since the planned diagram and actual operation for each direction on the main line is determined independently, it enables smooth operation on a double track.

- If the yard area is long, the yard can be divided into individual block sections and second home signals can be installed, enabling the following trains to approach.

This allows the relaxation of speed restrictions applied to the entire large-scale multifunction station/yard and limit the speed restrictions applied at specific areas.

Much of the freight being handled is bagged goods that are transferred to and from trucks at loading/unloading sidings, not only at large-scale multi-function station/yards, but also at medium-scale stations and intermediate stations. In the future, this should be changed to domestic container transport. Consolidation of these stations into a container terminal can be considered since goods are distributed/gathered by trucks, some distance of which is not a problem. This would also allow for a rearrangement of the loading/unloading siding and reception/departure tracks at many of the stations.

It should be noted that even if the current practice of loading and unloading at stations remains, it will enable the stations handling the freight to consolidate activities in consideration of the total volume of freight for the area. When the large-scale multifunction stations/yards are already located in densely populated areas with poor access due to traffic conditions, consolidating the loading/unloading sidings for these stations/yards outside the city would be effective for both streamlining yard operations and improving road traffic conditions.

4.2.3 Marshalling yards

In the era when freight was handled by marshalling yards and yard-to-yard operation systems, freight trains used to have the following flow of operations from the forwarding station to the receiving station.

- Forwarding station → Marshalling yard in the vicinity of forwarding station → Sorting by directions of travel → Marshalling yard in the vicinity of receiving station → Sorting by stations → Receiving station.

At present, the Indian Railways applies the unit train method by which single train units are sent from the forwarding station to the receiving station directly. Because of this, the marshalling yards that were located throughout the country, one time, and played such an important role are no longer required. However, these spacious yards still exist to this day. A good example of this includes the Mughal Sarai Yard and Andal Yard on the Delhi-Howrah Main Line on the Eastern Corridor.

In the present time, marshalling yards do not play a role in sorting, but still function in much the same manner as large-scale multifunction stations/yards.

Among these marshalling yards is the Mughal Sarai eastbound yard located almost midway along the Eastern Corridor where empty wagons, mainly those wagons used by freight trains hauling coal from the east to west, pass through. This yard is now used as a coal wagon inspection station. In other words, inspection is performed on the eastbound returning empty coal wagons, and the wagons requiring repair are separated at sorting tracks from those not requiring repair and new rakes are assembled using wagons that were repaired and wagons that did not need repair.

While most of the marshalling yards no longer serve as sorting tracks, a major renovation is too costly to be performed.

It should be noted that since marshalling yards offer the same function as large-scale multifunction stations/yards, they include such facilities as passenger stations, freight stations (loading/unloading sidings, including private siding/lead-in tracks), multi-function depots of rolling stock.

The issues facing marshalling yards are basically the same as those for large-scale multifunction stations/yards, which was mentioned earlier. While major renovations are not economically feasible, it is inevitable to increase the speed of train movement in the yards by improving the track layout. The objective is to reduce the number of turnouts, and reinforcing the structures to enable these marshalling yards to take on a new role that has changed.

The land for sorting tracks that remains in the marshalling yards is an extremely valuable asset. It can be used as rolling stock depots, facility maintenance depots in future plans for fortifying traffic capacity, or even as land for the development of the much-anticipated Inland Container Depot (ICD), etc.

4.2.4 Medium scale station/yard

Medium-scale stations/yards generally offer facilities such as the following: refuge tracks, passenger platforms, freight facilities (reception/departure tracks, loading/unloading sidings and private sidings/lead-in tracks). The network of Indian Railways is developing in a web-like pattern that has many junctions. Most of these junctions are medium-scale station/yards. Like the large-scale multifunction station/yards, a respectable number of medium-scale station/yards have speed restrictions that cover the entire station premises.

While the issues facing these medium-scale stations/yards are basically the same as those for large-scale multifunction stations/yards, it also reduces the speed restrictions which are relatively easier since there are fewer turnouts.

4.2.5 Intermediate stations

In terms of the number of stations, intermediate stations (with loops) that have only refuge tracks (loops) and passenger platforms are the most common.

Nearly all stations on the Delhi-Mumbai Main Line on the Western Corridor and on the Delhi-Howrah Main Line on the Eastern Corridor have refuge tracks because of the heavy traffic on these lines. Only a few stations do not have refuge tracks.

Most of these stations have a loop on each side of the main tracks of a double track. Some stations have only one loop on one side or between each main track of the double track so that it can be used by trains on either direction.

Refuge tracks of intermediate stations function sufficiently on lines that have a large number of trains travelling at significantly different speeds, such as super express passenger trains, express passenger trains, local passenger trains (i.e., those that stop at every station), high-speed freight trains (i.e., trains made up of the new type container flat wagons that are capable of travelling at 100 km/hr), and regular freight trains. However, the important factors here are improvement of line capacity and reduction of the travel time of low-speed trains, especially freight trains. And even though the high-speed freight trains are capable of travelling at 100 km/hr while super express and express trains can travel at 110 to 130 km/hr, the heavy load of the freight train means it will have slow acceleration after each temporary stop, so there are still many instances for it to be overtaken despite its fast maximum speed. This underscores the importance of refuge tracks.

There are two issues facing the intermediate stations.

- Excessively long distance between successive refuge tracks on all routes needs to be eliminated.
- The turnout for refuge tracks should be replaced to those that allow higher speed entry and exit. (See 6.2.6 for more information about turnouts.)

Currently both main lines have refuge tracks that are basically satisfactory in condition. However, in order to realise smooth transport, there is a need to further improve them to improve the conditions referred above.

On the main lines, there are also some sections that have three or four tracks. However, since these sections have a number of trains operating on them, and since these trains travel at various speeds, there is clearly a need for properly arranging the refuge tracks. It should be noted that, even though there are three tracks, the main track in the middle cannot be used simultaneously for both directions of travel and the refuge tracks play a large role because the trains of one direction have to be constrained to travel on one track when both directions are occupied.

4.2.6 Travel speed at turnouts

Nearly all of the turnouts used by Indian Railways are either 1/12 or 1/8.5. The speed restrictions for these turnouts are set at 30 km/hr and 15 km/hr respectively. (When it is a straight point, 1/12 also has a speed restriction of 15 km/h.)

In addition, due to problems in maintenance, double slip switches (DSS) / single slip switches (SSS) and diamond crossings have 15 km/h speed restrictions. In practice, there are some locations where the restriction is 10 km/hr.

And, in most of the large-scale multifunction station/yards where turnouts and DSS/SSS are extensively used, the speed restrictions for the entire yard are set at 15 km/hr due to its complex arrangement and the necessity of maintenance.

The following improvement is needed in response to this.

- The speed restrictions for the turning sides of turnouts should be increased.
- Reduction of the continuous speed restrictions for the entire yard at large-scale multifunction station/yards.

The current 15 km/hr and 30 km/hr restrictions of trailing speed on the turning side of turnouts are considered to be too much restrictive. Since the Indian Railways uses a 1,676 mm broad-gauge track so this speed provides too much margin for excess centrifugal force, which is determined by the radius of the lead curve, for preventing an overturn or ride discomfort. Since the axle load is large and, therefore, large lateral thrust acts, there is a need to carefully investigate the amount of structural strength and the level of maintenance that will be required. The speed restrictions should be raised within the permissible range after taking into consideration of safety and economic factors (i.e., maintenance costs).

If the speed restrictions are viewed from the standpoint of economics, in which the opportunity cost incurred due to application of the excessively low trailing speed, particularly the 15 km/hr speed, is compared with the maintenance costs, the results cannot be ignored.