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 3
TASK 2

OCTOBER 2007

JAPAN INTERNATIONAL COOPERATION AGENCY

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

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Exchange Rates

US$1.00 = INR42.98
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,

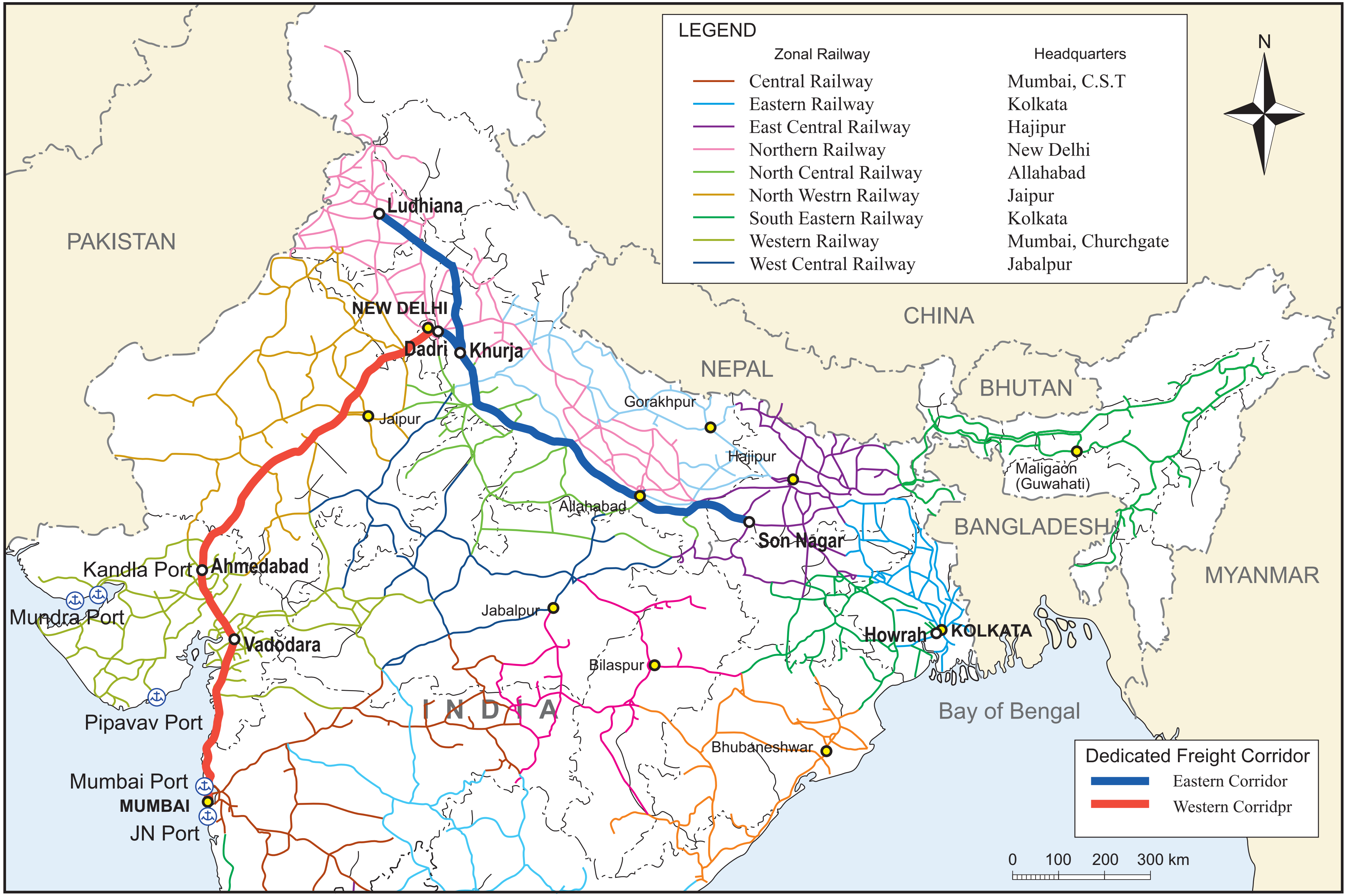
We have the pleasure of submitting herewith the Final Report on the “Feasibility Study on the Development of Dedicated Freight Corridor Delhi-Mumbai and Ludhiana-Sonnagar in India” (hereinafter referred to as the Study.).

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)

<table>
<tr><th rowspan="2">No.</th><th rowspan="2">Description</th><th colspan="2">Details</th></tr>
<tr><th>Western Corridor</th><th>Eastern Corridor</th></tr>
<tr><td rowspan="2">0</td><td colspan="3">Alignment</td></tr>
<tr><td></td><td>JNPT - Vasai Rd – Vadodara – Ahmedabad – Ajmer – Rewari - Dadri</td><td>Sonnagar - Mughal Sarai – Kanpur – Khurja - Dadri, and Khurja – Kalanaur - Dhandari Kalan</td></tr>
<tr><td rowspan="2">1</td><td colspan="3">Route length</td></tr>
<tr><td>Total Length
- Double line
- Single line</td><td>1,468 km
1,468 km
-</td><td>1,309 km
883 km
426 km</td></tr>
<tr><td rowspan="3">2</td><td colspan="3">Gradient</td></tr>
<tr><td>- Ruling gradient</td><td colspan="2">1 in 200 (5/1000)</td></tr>
<tr><td>- Steepest gradient in yards</td><td colspan="2">1 in 1200 (0.83/1000)
1 in 400 (2.5/1000) exceptional case</td></tr>
<tr><td rowspan="8">3</td><td colspan="3">Standards of construction</td></tr>
<tr><td>- Gauge</td><td colspan="2">1,676 mm</td></tr>
<tr><td>- Rails</td><td colspan="2">60 kg/m UIC/90 UTS rail, HH rail</td></tr>
<tr><td>- Sleepers</td><td colspan="2">PSC 1660 nos./km density for main line, 1540 nos./km density for loop line & sidings</td></tr>
<tr><td>- Points & crossings</td><td colspan="2">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</td></tr>
<tr><td>- Ballast</td><td colspan="2">300 mm cushion</td></tr>
<tr><td>- Maximum speed</td><td colspan="2">100 km/hr</td></tr>
<tr><td>- Type of traffic and axle load</td><td colspan="2">Double stack container movement on well type wagon and 5800 tonne train hauling with 25 tonne axle load</td></tr>
<tr><td rowspan="6">4</td><td colspan="3">Formation (Detour Route)</td></tr>
<tr><td>- Bank width for double line</td><td colspan="2">12.5 m</td></tr>
<tr><td>- Slope of embankment</td><td colspan="2">2H: 1V</td></tr>
<tr><td>- Cutting width for double line</td><td colspan="2">14.9 m
(11.9 m+1.5 m extra for each side for side drains)</td></tr>
<tr><td>- Slope of cutting</td><td colspan="2">1:1</td></tr>
<tr><td>- Blanketing</td><td colspan="2">0.60 m depth</td></tr>
</table>

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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ABBREVIATIONS LIST

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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
	BTU	British Thermal Unit
	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 Railways
	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 the results of the Task 2 included in the study.

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 and discussion held in various meetings.

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 were 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 is not able to complete the necessary freight transport service by itself only. Intermodal services to supplement the railway service, such as developments of ports, inland container depot (ICD), access road railway feeder lines, freight handling systems & latest information technology applications are absolutely indispensable. This means the DFC investment would not be effective enough, if the proper intermodal services are 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 2 study results. Study results on Task 0 and Task 1 are compiled in Volume 2. Followings are a list of reports of 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
REVIEW OF PETS-II REPORT

CHAPTER 2 REVIEW OF PETS-II REPORT

2.1 DEMAND FORCAST

The station-to-station Origin-Destination (O/D) pairs that would use the DFC were selected from the present station-to-station O/D matrices (2005-06), and the future traffic was projected based on the selected O/D pairs. Coal traffic was projected based on the future plans of thermal power plants and the transport plan of coal from the coalfields. Steel traffic, likewise, was projected based on the investment plans of steel companies. For the projection of other commodities, growth rates were assumed. In general, the growth rates were set at relatively low values except for international containers, in which an annual growth rate of 13% was applied for container traffic in all of India. The demand for rail transport was then projected based on the assumption of rail shares at the ports. Although this is quite optimistic, it is deemed reasonable because the traffic was estimated up to Year 2021 and assumed to be constant thereafter. Economic and financial analysis could not be done accurately, since only traffic on the DFC was projected.

2.2 TRANSPORT PLANNING

In PETS-II Report, the transport system of DFC is based on the Double Stack Container (DSC) with flat-type wagons and 25t as the axle load as per MOR's direction. The transport system that can operate trains at every ten minute interval is sufficient to satisfy the demand in the year 2021-22.

In Volume 2 the transport system was designed to satisfy the demand in 2031-32. As a result the transport system that can operate trains with the time interval of 8.6 minutes is proposed. In addition, the well-type wagons are recommended for DSC due to safety and its transport capacity that satisfies the demand.

In PETS-II Report, the number of dispatch centres for DFC was proposed to be less than that of the conventional dispatch system based on the CTC system. In Final Report the dispatch centres proposed to be centralized as a unified traffic control, is extremely essential for the recovery of any disruption that may occur. As for the staff allocation, Final Report proposes that the number of the staff per unit of DFC shall be reduced to a quarter of IR and based on current operation of KRCL Railway.

2.3 ALIGNMENT PLAN

2.3.1 Treatment of the Tunnel Section

A four kilometre tunnel section is proposed in the PETS-II for the DFC between Rewari and Tuglakabad/Dadri. In the report, it is indicated that a 60 m to 100 m difference in elevation exists between the two points near Sohna. In order to link the two points, a 4 km tunnel and a 1 km elevated section is considered to be necessary. Also, the planned tunnel site lying underneath the agricultural land from where ground water is sourced, there is concern for depression of ground water once the tunnel construction commences. Under these circumstances, a thorough engineering examination is required to establish basic design parameters, however it is estimated to take no less than two years to complete the study and design, in order to accomplish this task.

2.3.2 Consideration of Social/Natural Environmental Impact

The detour routes are proposed where the existing ROBs are very difficult to replace and/or the sections that are in the heavily built-up city area as mentioned in PETS-II Report.

RITES is proceeding its study in detail on FLS and its route alignment will be modified accordingly.

In the meantime, since the route alignment plan by FLS of RITES will be completed by the end of December this year, JICA Study Team (JST) will propose to modify wherever it is required, depending on the study with additional consideration of social/natural environmental impact during the review of PETS-II Report.

2.4 GRADE SEPARATION OF LEVEL CROSSING

In accordance with the policy set by the Ministry of Railways (MOR) to eliminate the level crossings and achieve grade separation by elevating the road, the PETS-II Report has not covered any design of the ROB, but merely conducts a brief study referring to the standard bridge drawings.

For those locations with less urbanisation, a few number of residential housing and the like are expected along the road leading to the level crossing, since the railway consists only of main line, application of bridge drawings is reasonable.

On the other hand, there are cases where level crossings in the proximity of the urban area become built-up by the advent of development of various commercial activity and residences along the road linking the level crossing. Since the level crossing is located adjacent to the station, the level crossing should be grade separated. Technical examination and design should be carried out for each of the ROB. The gradient of the existing ROB is designed for 2.5% maximum slope to allow the passage of non-motorised vehicles. If the vertical clearances for double-stack containers are considered, then the elevation difference of the road and the railway would become approximately 12 m. This will cause the length of the slope portion of the ROB becoming approximately 500m on each side and including the bridge section, the total length of the ROB could become more than 1,000 m in length. The provision of the ROB would also have an aspect of substantially affecting the ease of crossing on the ROB by pedestrians and non-motorised vehicles such as bicycles, rickshaw, horse-carriage, bullock-carts, etc. It is envisaged that issues such as noise and vibration during the construction of the ROB, dislocated residents along the road, compensation for business due to closure of level crossings, shall arise. The grade separation of the level crossing in urbanised areas will require an EIA at each crossing as well as trigger a debate within the community regarding the acceptance of the ROB, which is foreseen to be difficult in reaching a consensus.

The cost for constructing the ROB’s is the highest in percentage among the total project cost of PETS-II, and is the major component of the project cost. The ROB over–passing the existing lines, with the main beneficiary being the road traffic, there is no logical necessity for DFC to fund its cost for construction. The grade separation of the level crossing is a desirable project, however, it should be isolated from the DFC project and treated as a separate project and implemented by annual Railway/State budget.

Considering the convenience of the road traffic, JST’s view is that railway alignment should be elevated as a sweeping measure for resolving level crossing congestions of built-up areas having a lot of non-motorised vehicles traffic. As a long term perspective, the master plan for the grade separation may need to be reviewed.

2.5 TRACTION SYSTEM FOR THE WESTERN DFC

PETS-II report recommends an electrified traction system for the Eastern DFC and the diesel traction system of the Western DFC.

On the other hand, JST has opined its position on the economic advantage by comparing both the electrification and non-electrification scenarios. The rationale made by the JST in recommending the electrification of the Western corridor is based on the conclusion of the Team's examination of electrification scenario having an overwhelming advantage over non-electrified scenario even considering the investment for the transmission lines to the substations. This recommendation was written in the *Volume2 Task0&1*.

MOR expressed its position to initially not electrify the Western DFC at 4th Steering Committee held on March 2007. The decision was drawn on the basis of the apprehension of the double-stack container operation under wire with respect to the following issues being clarified by the Railway Board.

1) Double-stack container operation under wire is not a proven technology and safety issues are not cleared.
2) Requirement of electrification of non-electrified feeder lines has cost implications if DFC is planned as an electrified line.
3) The existing electrified lines do not support the double-stack container operation and inter-operability can not be realised.
4) Interruption to electrified lines during the loading of containers in the station yard

These issues were examined by JST. The study team would state their findings as follows in regard to each of the points:

Items (1) and (3): JST has investigated the situation of double stack container operation under OHE in China. As practiced in China, the study team has also examined the possibility of adopting double stack container transport on well type wagon in place of flat wagons from the aspect of numbers based on demand forecast and their planning for future. Well-type double-stack container transport are already in use in China and U.S.A., etc.

Item (2): The investment on electrification of the feeder routes could be prioritized and spread over sufficiently long time until traffic on them grows adequately. This would minimize cost impacts.

Item (4): The Container terminals and yards of electrified routes always have diesel shunters to move the wagons for loading and unloading.

2.6 SIGNALING SYSTEM

PETS-II proposed to adopt the Absolute Block System (ABS) in single line section and the Automatic Block System in double line section as block signaling system. However, PETS-II did not indicate any train detection system. It seems that the report keeps DC track circuit in mind. The Report mentioned also that the train detection system with GPS has cost merit, but the GPS system is not proven. Then the Report proposed to establish a test section on the limited line of DFC.

JST basically agrees with the introduction of the ABS as proposed in the Report. However, JST recommends the AF track circuit for train detection to reduce track maintenance, improve reliability of the track circuit, and solve the imbalance of returning traction current by using both rails for turn-around. The AF track circuit technology has been proven in Japan.

PETS-II proposed the TPWS (Train Protection and Warning System) as the Automatic Train Protection System (ATP). However, this system may not be sufficient to protect train collisions and pass signals in times of danger. Therefore, JST recommends the introduction of a full-speed checking ATP named "advanced TPWS" which will be integrated into the total traffic control system.

Note: There are many types of ATP with speed check function in Japan, for example ATS-P. The name ATS (Automatic Train Stop Control System) is generally used in Japan instead of ATP, but it is not generally used internationally. The name TPWS is familiar term in India.

2.7 TELECOMMUNICATION SYSTEM

The PETS-II proposes the same equipment configurations as presented earlier in the PETS-I Report, and JST basically agrees with the principles presented therein. Following points shows the proposed telecommunication system by PETS-II.

Fixed Communication:	Optical Fibre Cable (STM-1, STM-4), audio and data communication function
Mobile Communication:	GSM-R, interval of base station at 10 km, audio and data communication function
Switching System:	Digital Switch
Dispatcher telephone:	Selective button type

2.8 PROJECT COSTS

The costs have been enhanced in PETS-II compare with PETS-I. However following route additions account for a part of the increase.

1)	Khurja – Dadri section	:	46 Km
2)	Khurja – Ludhiana (Dhandarikalan) section	:	394 Km

Other than the above reason, in PETS-II the number of road over bridges (ROB) are increased drastically an effort abolish all the level-crossings, based on the Ministry of Railways (MOR) policy.

The Estimated PETS-II costs appeared to be not premised for international competitive bidding and need to employ international consultants & construction contractors.

Thus it was necessary to review the cost estimate according to these considerations.

2.9 NEW INLAND CONTAINER DEPOT (ICD) PLAN

The PETS-II report makes the examination of Logistic Parks, and concludes the provision of new ICD's along the DFC as a measure to cope with the increase of future container traffic demand.

The Report also proposes the construction of a minimum of two Logistics Parks in the National Capital Region (NCR). However, the study of new ICD around Delhi region in consideration of stage construction is not found in this report.

The location of the proposed ICDs' are not mentioned, however the Study Team has come to understand that there exists the following plan for new ICDs after discussions with CONCOR and Gateway Terminals India Pvt Ltd Officials.

Direction	Planned Location of ICD (Operator)
North (Ludhiana, Punjab)	- Sonipat (CONCOR) - Panipat (BOXTRANS) - Loni (APL, BOXTRANS, CWC)
East (Moradabad)	- Nil
South (Jaipur)	- Patli (ADANI, under construction) - Rewari (CONCOR)
West (Rohtak)	- Nil
NCR	- Bijwasan (CONCOR)

2.10 EXAMINATION OF ROLLING STOCK

The PETS-II report presents the transport plan and the required number of rolling stock based on the performance of the existing rolling stock. In accordance with the transport condition of the DFC, the Study Team proposes the application of 6-axle 9,000hp and 8-axle 12,000hp locomotives. RITES has not made any concrete examination of the realisation of the double stack transport system nor the freight wagon applicable for high axle load transport. However, JST carried out a conceptual design which is presented herein.

In regard to transport through double stack containers PETS-II has examined infrastructure and operating planning assuming DSC on flat-type wagons for the Western Corridor, and DSC on well-type wagon for the Eastern Corridor. However, detailed examination on the well-type wagon was not done in the PETS-II. And it is not clear how 90 km/h as the maximum speed of DSC on well-type wagon has been adopted.

On the other hand, JST has adopted 75 km/h as the maximum speed of DSC flat-type wagon according to the oscillation test results conducted by RDSO and, 100 km/h as the maximum speed of DSC on well-type wagon based on the practices in USA and China’s rail transport systems.

In regard to the pantographs of electric locomotives, the PETS-II presented examples of European suppliers to allow wide range movements corresponding to the OHE height 7.2 m for DSC on flat-type wagon and minimum of 4.8 m for the existing line. JST shows a conceptual design and furnishes examples of the pantographs for wide range of movements as required for a practical application.

2.11 OUTLINE DESIGN OF DFC

As with PETS-II Report, the outline design of the railway facility has not been prepared. The alignment of the route and the outline design of the junction stations presently are going on and expected to be completed by December of 2007 at the earliest. Since the JICA Study was required to complete by September 2007, on submission of the draft final report, JST has completed the Final Report with doing the review work of PETS-II in parallel to the completed portion of FLS of RITES, and supporting FLS of RITES through this.

CHAPTER 3
ESTABLISHMENT OF PHASED DEVELOPMENT SCENARIO FOR DEDICATED FREIGHT CORRIDOR

CHAPTER 3 ESTABLISHMENT OF PHASED DEVELOPMENT SCENARIO FOR DEDICATED FREIGHT CORRIDOR

3.1 OBJECTIVE AND PREREQUISITES FOR ESTABLISHING THE DEVELOPMENT SCENARIO

The Government of India has aspiration to complete this project in five years from 2008 to 2012. However, technical examination by JICA Study Team (JST) has revealed that in some sections of corridors commencement of construction from 2008 would be difficult due to the lack of reliable design, and unsolved technical/environmental issues. On the other hand, some sections have sufficient line capacity compared to the projected demand and the early implementation of the project may not be necessary.

To undertake Task 2 of the Scope of work, "Examination of feasibility of the dedicated freight corridor", it is necessary to set up a realistic development scenario for the technical and environmental examinations/reviews. Subsequently, the economical and financial feasibility of phased development scenario can be analysed. The establishment of development scenario, accordingly, was required as precondition to undertake the JICA feasibility study.

In general, the following requirements should be met in the infrastructure development projects to ensure that the project is feasible.

1) The traffic is so heavily congested that the implementation of the project is justified.
2) The basic plan had been established based on sufficient engineering deliberation.
3) Environmental impact assessment is carried out based on the basic plan, and social issues regarding environmental and social aspect is addressed.
4) The particular section suffices to be established as an independent Project, and the project effect is generated.

Whether the above requirements are met in the feasibility study is essentially reviewed by the project appraisal mission of international lending organizations including JBIC. It was recognized that the loan from international lending organization is indispensable as the huge investment cost is needed to implement this project. JBIC is planning to dispatch appraisal missions to conclude the loan agreement in March next year. Accordingly, the requirement of appraisal process should be taken into account while detailing the project development scenario.

In this connection, the entire project should be divided into several sections and the project feasibility on each section should be evaluated. Subsequently the phased development scenario is prepared based on evaluated feasibility of each section.

The followings are the procedures in deciding the phased development scenario.

1) To identify the condition for the feasibility of the project
2) To divide the project into sections considering the feasibility requirement
3) To evaluate feasibility of each section
4) To decide phased development scenario composed of sections based on above evaluation

3.2 UNDERSTANDING THE CONDITION FOR THE FEASIBILITY OF PROJECT

3.2.1 Situation of Demand and Line Capacity

The necessity of implementing the Project should exist as a precondition for its implementation. As a general rule, if the transport demand has increased and already reached equivalent to the existing capacity, or is projected to exceed the capacity in the near future, then it can be said that there is urgency for the implementation of the project.

The seriousness in the level of traffic situation varies from section to section in both Eastern and Western corridor. While some sections are near saturation, other sections still have capacity and implementation of the project in such sections is not urgent.

The level of traffic situation is explained by the ratio between the volume of traffic and line capacity. JST evaluated the seriousness in the traffic situation of each section in comparison of the line capacity of the existing lines as estimated in *chapter 7 of Volume 2*. The value of line capacity applied in the *Volume 2* assumes that the existing lines are improved to adopt the automatic signalling, track layout of station yard is improved and cleared of bottlenecks, and other railway infrastructures are improved and maintained to a good condition. In this connection, the discussion with Ministry of Railways (MOR) regarding the value of the line capacity concluded that the following conditions need to be considered:

1) The condition of the existing railway infrastructure is not maintained to a satisfactory level and the frequency of break down or malfunctions of signalling, telecommunication, track and other facilities is high. Thus, the effective line capacity need to be reduced from the one derived by calculation.

2) The implementation of DFC Project starting 2008 is already approved by the Cabinet. MOR has decided to defer the improvement works of the existing lines which have conflict with the DFC. Thus, it is decided that no improvement works in advance to the DFC will be made for the signalling system of those aforementioned lines.

Based on the above results, the level of stringency of the traffic situation on each section is calculated applying the following value of line capacity (20 hour operation) utilization by the Railways:

Table 3-1 Line Capacity Applied to Calculate the Level of Seriousness of Traffic Situation

Type of Track	Line Capacity (Number of trains/day/direction)*	
	IR	JST
Single track	20 (ABS)	25 (Automatic signalling)
Double track	55 (ABS)	110 (Automatic signalling)
	70 (Automatic signalling)	
Triple tracks (Double + Single)	75 (ABS)	135 (Automatic signalling)
	90 (Automatic signalling)	

*Note: MOR and Calculation by Study Team

3.2.2 Present Status and Maturity of Basic Plan

The discussions with RITES and DFCCIL reveal that the progress status of the on-going DFC preliminary engineering design undertaken by RITES is as follows:

1) For the alignment final location survey, field survey and route design work is going on. The work is expected to be completed by September 2007 for priority sections and in December 2007 for the other sections.

2) The progress and time frame to complete the design for station yard is same as 1) above.

3) The hydrological model analysis and preliminary General Arrangement design for

long-span Bridge will be completed in May 2008.

4) Geological survey and preliminary design for tunnel section between Rewari and Dadri will be completed within a period of 3.5 years.

5) The consultant to commence the detail design of ROBs shall be separately procured. (Completion period is not known)

As stated above, the discussions on the parameters of the preliminary designs for route and structure have not yet been completed and the part of outputs by RITES, will be first submitted after October 2007. Accordingly JST has decided the following methodology for preliminary designs.

1) JST prepare the guidelines of preliminary design for the design of alignment, station yards, and bridges, and present it to the Indian side.

2) JST request the representative of Indian side to agree to undertake the preliminary engineering design complying with the guideline design.

3) JST carry out the environment social consideration survey based on the guideline designs subject to the condition that Indian side accept the preliminary design prepared by complying with the guideline design.

Based on PETS-II review and technical meetings with RITES, the following concerns in preliminary design were reviewed for the completeness for appraisal by international lending agencies.

1) There are a number of ROBs whose replacements are necessary but a number of squatters are occupying land along the parallel and adjacent section of the existing line. For these sections, the early commencement of construction of DFC utilizing loan from international lending agencies would be difficult. Therefore, the review of the PETS-II route design including the study of detour route is required. The existing line has the sections whose gradients are greater than the standard gradient of DFC of 1/200. JST will examine these sections individually.

2) Large scale resettlement can be avoided by minor route changes in the detour sections. Since most detour sections are situated on flat terrain, the horizontal and vertical alignment of the detour section are confirmed not having serious engineering issues.

3) The Junction station at Mughal Sarai has complicated connections for several existing lines and several existing yards. The controlling parameters of preliminary design have not been finalised. Hence, it would take longer to complete the preliminary design.

4) It will take approximately 2 years to complete the basic design of tunnel section in Rewari-Dadri section since geological survey and detailed technical examination are necessary.

5) Special technical methodology would not be necessary to construct the large span bridges. It should be noted that the span has to have enough length to ensure adequate water flow capacity during the flood season.

6) ROBs can be divided into two types, 1) to replace the existing ROBs and 2) to construct new ROBs replacing the existing crossings. The technical examination and preliminary design has not been undertaken for ROBs so far. The Indian side will undertake this work from now on. Accordingly there are no ROBs whose preliminary design can be prepared immediately.

3.2.3 Environmental and Social Considerations

(1) Requirements of International Lending Agencies

In the case where financial source for the DFC Project is supposed to apply for the international lending agencies such as JBIC, ADB, and the WB, the following would be considered.

1) In the case of JBIC, the EIA document has to be approved in the recipient country in 120days before the Loan Agreement (L/A), for environmental category A under the JBIC Environmental Guidelines[1].

2) ADB supports the recipient country on preparation of the EIA and/or RAP under the technical assistance scheme (TA).

3) The WB allows recipient country to conduct relevant studies on EIA and/or RAP, and implement the RAP under the loan scheme.

Even if other requirements are satisfied, the recipient country can not receive financing from the international lending agencies until EIA process is completed. In the case, implementation of the project will be delayed. Therefore, requirements on environmental and social considerations for the DFC project should be confirmed well in advance to meet the requirements adequately on schedule.

(2) Important Points on Environmental and Social Considerations

There are many cases in India that the environmental and social issues become critical in implementation of the project. As mentioned in this section, based on progress of preparation of basic design by Indian side and result of the Environment and Social Impact Mitigation Measures Study (ESIMMS) for the Guideline Design prepared by the JICA Study Team[2], the following should be taken into account for implementation of the project from environmental and social considerations viewpoints.

1) There are many ROBs in the parallel section along the existing railway line that require replacement of the ROBs for the DFC project. Also, there are many sections where relocation of the squatters is required for the DFC project. Due to such reasons, there are some places along the existing railway line where implementation of the DFC project is not feasible or very difficult. For such places, re-examinations of the railway route including detour were required since necessary study and procedures at EIA level and implementation of requirements on the environmental and social considerations will take far longer time for the proposed basic design by the Indian side.

2) The detour sections proposed by Indian side were modified to avoid or minimize large-scale involuntary resettlement as Guideline Design proposed by the JICA Study Team.

3) Farming activity is widely practiced by using underground water in the proposed tunnel section between Rewari and Dadri. Therefore, if decline of the underground water is caused by construction of the tunnel, social impact will be critical issue in the area. Further, some issues such as land acquisition in the open-cut section and natural impact in the long slope section, have to be alleviated in the EIA level study. In addition, proposed tunnel site is located in the Sohna Hill in the Geo-physical Eco-sensitive Area. Therefore, it will take time for the field survey and necessary procedure for the EIA level study.

4) For construction of long span bridges, natural and social impacts are expected to minimize at certain level by implementation of adequate measures. Appropriate length of the bridge for maintenance of flow capacity is secured under the Guideline Design proposed by the

1 JBIC Guidelines for Confirmation of Environmental and Social Considerations (2002)
2 The ESIMMS is equivalent to the Environmental and Social Considerations Study at EIA Level under the JICA Guidelines for Environmental Social Considerations (2004).

Study not to raise flood level in the upper stream in the flood.

5) In the case where the ROBs located in the urban area are replaced as well as in the case of new construction of the ROBs, large-scale social impacts are expected to occur. For such ROBs' construction, EIA level study will be required for each ROB in the case where international financing is applied for the construction of the ROB. It will take far long time.

3.3 SEGMENTATION OF THE PROJECT

Taking into account the requirement for project feasibility, the project has been divided into various sections, and the characteristics of each of these sections have been examined. Figure 3-1 presents the divided sections in both Western and Eastern corridor.

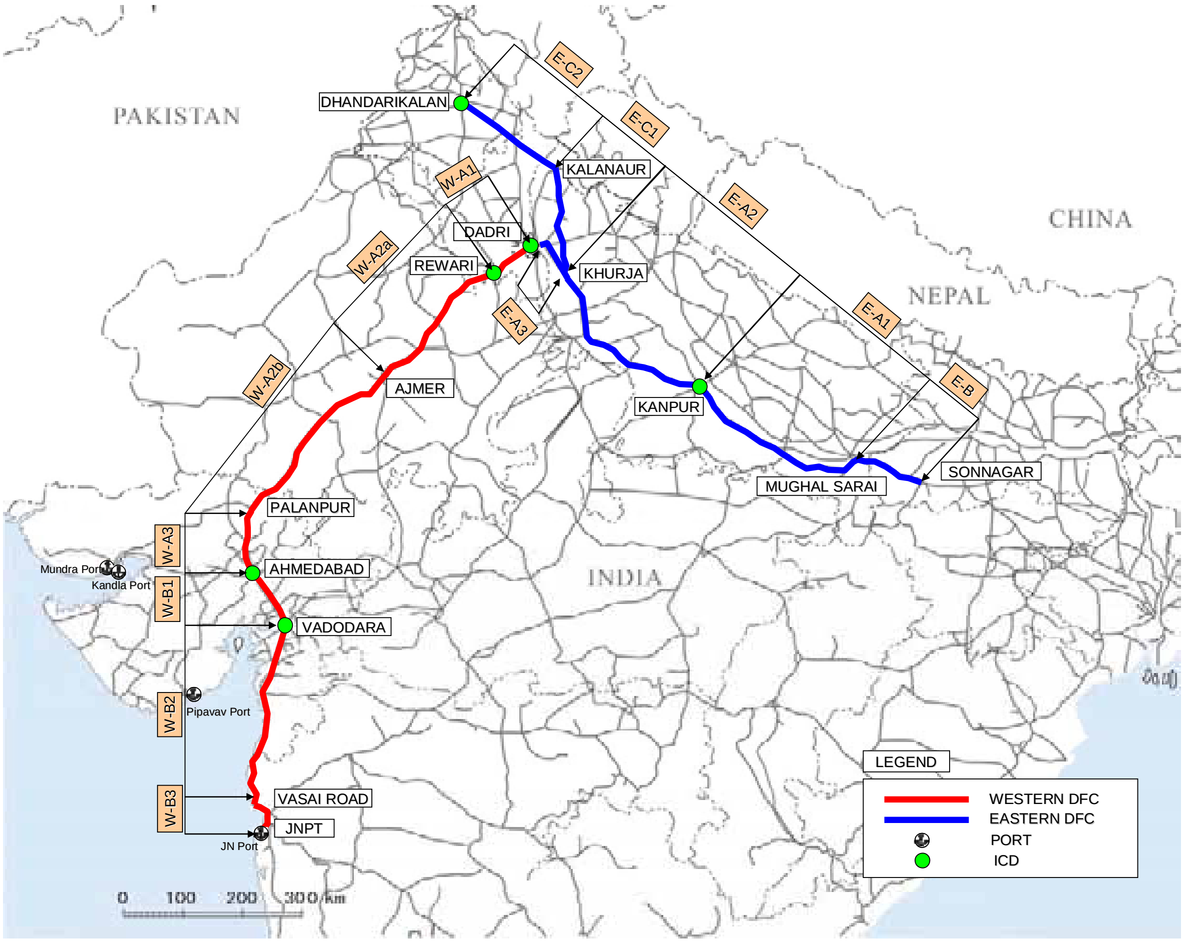


Figure 3-1 Section Division for Phased Development

3.3.1 Section Division in Western Corridor

The Western corridor has been divided into two sections, Dadri-Ahmedabad section (WA section) and Ahmedabad-JNPT section (WB sections) and further subdivided as follows.

(1) Dadri - Ahmedabad section (WA section)

This section directly connects the Northern Capital Region (NCR) and the cities along the western coast of India. The section of the DFC will become the strategic logistic route between industrial areas in Northern India including Delhi Metropolitan Area/Ludhiana and a cluster of ports in Gujarat (Pipavav, Mundra, and Kandla).

Considering the regional characteristics, this section has been subdivided into following four sub-sections.

1) Dadri - Rewari Section (W-A1)

The section, approximately 120km, includes a tunnel and viaduct section. Due to the tunnel, this section involves higher risk for implementing the project. Also the urban area is significantly expanding around metropolitan area hence land acquisition could be problematic. These difficulties make this section as separate section despite its short length. If this section is not selected in the earlier stage of the project development scenario, a provision of a new ICD is required to secure the logistic function serving the NCR.

2) Rewari - Phulera - Ajmer (W-A2a)

Most of this section is planned parallel and adjacent to the existing line. The metre gauge Rewari-Phulera section is presently being modified to broad gauge. The entire Rewari-Ajmer section, presently a single broad gauge line, is planned to be converted into a double line in near future.

The regional development of this section falls behind compared to other sections and the population density still remains low. The squatters along the existing line are small in numbers in urban areas and therefore, not a significant problem. Obstacles for constructing the new freight line are not significant and the risk for the implementation of the project in this section is the least among other sections.

3) Ajmer - Palanpur (W-A2b)

Most of this section is planned to be constructed parallel and adjacent to the existing line. Also, most of this single line section has enough space to construct the new line adjacent to it. Similar to WA-2, this section has less obstacles in constructing the new line.

The existing line passes through Balaram Ambaji Wildlife Sanctuary near Palanpur, and the alignment proposed in PETS-II is planned parallel to the existing line. Since government approval of any development within the wildlife sanctuary takes time, JST proposes a detour route avoiding the wildlife sanctuary to minimise the impact on the natural environment and to avoid the approval process.

4) Palanpur - Ahmedabad (W-A3)

The detour route is planned at coastal side of this section. The feeder line transversing this detour route links the central region of Ahmedabad and major ports in Gujarat. The obstacles in social environment are significant since this section passes through urbanized area of Ahmedabad. Accordingly the section was divided into smaller sub-sections despite its short length.

(2) Ahmedabad - JNPT (WB)

This section connects the two large urbanized cities in western coastal of India, i.e. Mumbai and Ahmedabad. Due to the increase in demand, the expansion of line capacity is urgently required. In terms of tight demand situation, this section is identified as highest priority section.

On the other hand, this area is broadly urbanized and the obstacles in resettlements are expected to be encountered. Many ROBs exist in this area. The new line construction of this section includes the difficult ROB replacements and grade separation of level crossing in heavy traffic volume area.

This section has been sub-divided into following three sub-sections considering the regional characteristics.

1) Ahmedabad - Vadodara (W-B1)

Detour route has been adopted for most of this section. Since this section is anticipated to incur social environmental impact, and there are long-span bridges which cross over rivers that overflow during flood season, the section was divided into smaller section to deliberate on the issues.

2) Vadodara - Vasai Road (W-B2)

The train operation on the existing line of this section has the highest density among all sections. On the other hand, social impact are expected to be encountered due to the highly built-up situation. Since there are several large rivers that overflow during flood season, flood control measures will also be required to be examined.

3) Vasai Road - JNPT (W-B3)

This portion of DFC is to link Vasai Road and western end of JNPT. Since the existing line has double tracks and passenger trains are not being operated at all in this section, the line capacity of this section has more room compared to Vadodara-Vasai Road section.

3.3.2 Section Division in Eastern Corridor

Eastern DFC has been mainly divided into 3 sections, Dadri - Mughal Sarai、Mughal Sarai - Sonnagar and Khurja - Ludhiana These sections were further divided into sub-divisions

(1) Mughal Sarai – Dadri (EA)

This section is main part of the eastern corridor. Most of the freight trains mainly with coal pass through this section. The line capacity of existing line is already saturated due to large demand hence this section is highly prioritized for construction. The existing line of this section is already double track and electrified. The section is subdivided into following 3 sections.

1) Mughal Sarai - Kanpur (E-A1)

The demand and capacity relation for this section is expected to be different from neighbouring Kanpur-Khurja section since there is a link to Lucknow at Kanpur and several feeder lines are connecting this section.

2) Kanpur - Khurja (E-A2)

This section has the tightest demand compared to the existing line capacity.

3) Khurja - Dadri (E-A3)

This section links Western and Eastern DFC. The expansion of existing line to three tracks is presently going on and the line capacity will be strengthen due to this expansion.

(2) Mughal Sarai－Sonnagar (EB)

On this section, since existing line has three tracks, the line capacity of this section is larger than the double track section and is more than that of Mughal Sarai - Kanpur section, it is estimated that the section can be used without any capacity enhancement works. Therefore a flexible solution would be to construct the section as double-double track project of existing route in stead and not as a new freight line project. Accordingly it is decided to examine the project impact from this aspect.

(3) Khurja - Ludhiana (EC)

This section, bypassing around Delhi metropolitan area, is linking Eastern India area and Punjab State districts where the main industrial city of Ludihana is located. As the existing freight trains such as coal transport trains are operated from Eastern India to Ludhiana district through Delhi metropolitan area, the new freight line construction of this section will contribute to improve the congested issues around metropolitan area. This section is further sub-divided into the following two sections.

1) Khurja - Kalanaur (E-C1)

This section connects two main lines. Because the exiting line of this section is single track and the line capacity is not so large, route through Delhi is selected in existing operation. After improving this line, the train will be able to detour around congested metropolitan area.

2) Kalanaur - Ludhiana (E-C2)

This section has double track line and has a little margin of the track capacity and this study is carried out separately.

3.4 EVALUATION OF FEASIBILITY CONDITION IN EACH SECTION

The evaluations of feasibility in each section are presented in Table 3-2 (1), Table 3-2 (2), Table 3-3 (1) and Table 3-3 (2).

Table 3-2 Evaluation of Project Feasibility at Each Section in Western DFC (1) (Demand and Technical)

No.	Section	Length (km)	Nos. of Detour Section	Detour section Length (km)	Ratio of Detour (%)	The time when transport demands reaches equivalent to capacity	Reliability of Design	Difficulty of Construction （ROB to be replaced）	Necessary Provision in case that the section is not constructed
W-A1	Dadri - Rewari	117	1	117	100 %	2010 (Dadri – Ghaziabad Jn)	**【Route Design】It will take more than 2 years to design tunnel route since natural condition survey, technical examination and EIA are needed.** 【Station Yard Design】The design of Rewari J/S shall be reviewed after completion of tunnel route design and ICD plan of Delhi Metropolitan Area. 【Important Bridge】 Yamuna River /Length 370m	Total Number of ROB： 5 in the feeder line to TKD Number of ROB whose replacement is difficult： Above 5	・ New ICD between Rewari and Delhi ・ Short-cut route between Delhi Cantt. and Brar Square（To improve the connection to TKD and Dadri） ・ Electrification between Rewari and Brar Square/Patel Nagar
W-A2a	Rewari - Ajmer	290	3	49	17 %	2010	【Route Design】The detour routes at Ringas, Phulera, Kishangarh have to be examined and would be finalised within this year. 【Station Yard Design】The draft design would be prepared within this year. 【Important Bridge】 Non	Total Number of ROB： 0 Number of ROB whose replacement is difficult： 0	Gauge Conversion between Ajmer and Rewari
W-A2b	Ajmer - Palanpur	368	1	36	10 %	2010	【Route Design】The detour routes at Ajmer and Palanpur have to be examined and would be finalised within this year. 【Station Yard Design】The draft design would be prepared within this year. 【Important Bridge】 Non	Total Number of ROB： 0 Number of ROB whose replacement is difficult： 0	Improvement to double track for existing line
W-A3	Palanpur – Ahmedabad	124	1	71	57 %	2010	【Route Design】The detour routes at Ahmedabad and Mahesana have to be examined and would be finalised within this year. 【Station Yard Design】The draft design would be prepared within this year. 【Important Bridge】 Saraswati River /Length 330m	Total Number of ROB： 0 Number of ROB whose replacement is difficult： 0	Improvement to double track for existing line
W-B1	Ahmedabad - Vododara	136	1	136	100 %	2010	【Route Design】The detour route at Vasad has to be examined but it would be finalised within this year. 【Station Yard Design】The draft design for Makarpura J/S including the diversion of existing line to Mumbai/JNPT would be prepared within this year 【Important Bridge】 1. Sabarmati River /Length 2,800m, 2. Sabarmati River2 /Length 2,290m 3. Mahi River/550m	Total Number of ROB： 0 Number of ROB whose replacement is difficult： 0	Improvement of signal and station yard to strengthen the line capacity（Especially Vadodara station）
W-B2	Vadodara – Vasai Rd.	344	2	65	19 %	2010	【Route Design】(Miyagam Karjan)：Field survey and technical examination is needed for replacement of ROB and detour route ・(Surat) Field survey and technical examination is needed for detour route (Surat-Virar)：There are seven existing ROBs to be replaced and crossing with heavy transport volume hence the review of route including detour route would be necessary. (Virar-Vasai Rd.) ：There are two ROBs to be replaced in urban area and squatters along the existing line. Drastic review of design would be needed. 【Station Yard Design】The design review of Vasai Rd J/S is needed. Due to the change of route in Surat Detour, the review of Gothangam J/Sis required 【Important Bridge】1. Narmada River/Length 1,450m, 2. Tapi River/Length 850m, 3 Mindhola River/Length 270m, 4. Navsari River/Length 410m, 5. Ambika River (South)/Length 230m, 6. Ambika River (Center)/Length 270m, 7. Ambika River (South)/Length 230m, 8. Valsad River/ Length 320m, 9. Par River/Length 320m, 10. Damanganga River/Length 370m, 11. Vaitarna River (North)/Length 520m, 12. Vaitarna River (South)/ Length 460m	Total Number of ROBs: 10 **Number of ROBs whose replacement is difficult： 7** **1.Vasad（Land acquisition problem）** **2.Vapi（Urban Area, 2km length、2 lanes）** **3.Dahanu Road （Urban Area, 2 lanes）** **4.Boisar （Urban Area, 4 lanes）** **5.Virar （Urban Area, Land Acquisition Problem, New construction of ROB is ongoing）** **6.Nala Sopalra （Urban Area, Land Acquisition Problem）** **7.Vasai RD （Urban Area, Land Acquitision Problem）**	Improvement of signal and station yard to strengthen the line capacity
W-B3	Vasai Rd. - JNPT	89	0	0	0 %	**2020**	**【Route Design】This section has steep undulation. The urbanization is progressed and the site for construction is limited hence the route review with topographic data would be necessary. A tunnel construction might be necessary at Panvel** 【Important Bridge】Ulhas River /Length 330m	Total Number of ROBs: 12 **Number of ROBs whose replacement is difficult： 5** **1.Kopar RD (2 Bridges on NH3・Large transport Volume・Large suspended utility pipes)** **2.Navede RD （Urben Area, 2 Lanes）** **3.Kalamboli （Urban Area, 4 Lanes）** **4.Panvel JN （Urban Area, 2 Lanes）** **5.JNPT （2km Length, 4 Lanes, Large ROB）**	

Table 3-2 Evaluation of Project Feasibility at Each Section in Western DFC (2) (Environmental and Social Considerations)

No.	Section	Section Length (km)	Evaluation on Social Environmental Aspects			Evaluation on Natural Environmental Aspects	
			Land Acquisition Area for Railways and ROB and its difficulty	Location where the Resettlement is Required and its Scale (Number of Houses)	Location where the Resettlement of Squatter is Required and its Scale (Number of Houses)	Affected Natural Environment Wildlife Sanctuaries/Recorded Forests, etc.	Other Natural Environmental Issues
W-A1	Dadri - Rewari	117	Land Acquisition Area for ROB: 31 ha Land Acquisition Area for Railway: 387 ha **As the new section is located in the fertile agricultural area around NCR, the land acquisition cost would be high. Urbanization of the TKD link section is significantly progressed hence the land acquisition would be difficult.**	Rewari－Dadri: Approx. 180 houses **TKD Link Section: Approx. 250 houses and a lot of commercial building**	**TKD Link Section : Approx. 1,250 houses**	A tunnel and a bridge of DFC have been planed to cross hills of an Eco-sensitive Area, with a elevation of approx. 100m, in Aravalli Range, the southern Haryana State. By the tunnel construction, the ground water level in the area would be affected and decrease. Trees along the exiting line would be affected by the project.	The potentially affected area in Aravali Hills is being studied at the IEE level. The DFC line would cross Yamuna River, an important river.
W-A2a	Rewari - Ajmer	290	Land Acquisition Area for ROB: 441 ha Land Acquisition Area for Railway: 496 ha As the section is located in the infertile dry area, the land acquisition would be relatively easy.	Parallel Section : Approx. 85 houses (Area between built-up urbanized zones)	Khori Station : Approx. 25 houses	12 Reserved Forests within 1km from the existing railway would be affected. The total length of the forest to be affected is approximately 12.2km in parallel to the existing railway. Trees along the exiting line would be affected by the project.	The affected trees are being studied using a sampling method in the site after identification of the affected forests. The affected trees alongside the existing railway are being studied by analysis of the video data and other secondary data in addition to the field survey.
W-A2b	Ajmer - Palanpur	368	Land Acquisition Area for ROB: 413 ha Land Acquisition Area for Railway: 413 ha As the section is located in the infertile dry areas, the land acquisition would be relatively easy.	Parallel Section : Approx. 120 houses (Area between built-up urbanized zones)	None	The DFC line is planned to pass through the western edge of Balaram Ambaji Wildlife Sanctuary for approx. 2.4km in the parallel section. 6 Protected Forests and 4 Reserved Forests within 1km from the existing railway would be affected by the project. Trees along the exiting line would be affected by the project.	The affected trees will be studied using a sampling method in the site after identification of the affected forests. The affected trees alongside the existing railway will be studied by analysis of the video data and other secondary data in addition to the field survey.
W-A3	Palanpur – Ahmedabad	124	Land Acquisition Area for ROB: 155 ha Land Acquisition Area for Railway: 986 ha As this section passes the fertile agriculture area in the suburbs of cities, the land acquisition cost would be high.	Detour Section between Amedabad to Mahesana: 30 houses	None	Trees along the exiting line would be affected by the project.	The affected trees are being studied using a sampling method in the site after identification of the affected forests. The DFC line would cross Saraswati River, an important river.
W-B1	Ahmedabad - Vododara	136	Land Acquisition Area for ROB: 47 ha Land Acquisition Area for Railway: 815 ha This section is a detour which passes the fertile agriculture area in the suburbs of cities. Therefore, the land acquisition cost would be high.	Detour Section: Approx. 50 houses	None	Trees along the exiting line would be affected by the project.	The affected trees are being studied using a sampling method in the site after identification of the affected forests. The DFC line would cross 2 important rivers, such as Sabarmati River and Mahi River.
W-B2	Vadodara – Vasai Rd.	344	Land Acquisition Area for ROB: 386 ha Land Acquisition Area for Railway: 1,036 ha Because urbanization is significantly progressed along the existing line, land acquisition would be difficult around cities and stations. **In the urban area, land acquisition for ROB replacements seems to be large and difficult.**	**Parallel Section: Vasai Rd/70, Nala Sopara/170, Virar/30, Palghar/10, Boisar/10, Vangaon/12, Dungri/12, Navsari/5, Maroli/38, Sachin/10, Sayan/13, Kim/10, Kosamba/5, Ankleshwar/15, Myangam Karjan/10, Itola/10, Others 10** **ROB: Vasai Rd/20, Nala Sopara/20, Virar/30, Boisar/20, Dahanu Rd/3, Vapi/150**	**Vasai Rd/ 20, Nala Sopara/32, Virar/80, Palghar/150, Boisar/80, Vangaon/9, Umargaon/17, Pardi/12, Bilimora/12, Navsari/60, Maroli/50, Miyangam Karjan/30, Others/10**	4 Reserved Forests within 1km from the existing railway would be affected. The total length of the forests to be affected is approx. 7.0 km in parallel to the existing railway. Trees along the exiting line would be affected by the project.	The affected trees are being studied using a sampling method in the site after identification of the affected forests. The DFC line would cross 10 important rivers, such as Vaitarna River, Daman Ganga River, Par River, Auranga River, Kaveri River, Ambika River, Anna Poorna River, Mindhola River, Tapi River and Narmada River.
W-B3	Vasai Rd. - JNPT	89	Land Acquisition Area for ROB: 78 ha Land Acquisition Area for Railway: 123 ha It is expected that land acquisition around Panvel J/S and Dombivli Station are difficult.	Parallel Section: 50 houses ROB: : 6 houses between JNPT and Panvel J/S	**Dombivli Sta. Approx. 430 houses (2 sites), Panvel Sta./15 houses**	3 Protected Forests within 1km from the existing railway would be affected. The total length of the forest to be affected is approx. 2.0 km in parallel to the existing railway.	The DFC line would cross Ulhas River, an important river.

Note) The information in the table is based on the results of Environmental and Social Considerations Study (IEE level)

Table 3-3 Evaluation of Project Feasibility at Each Section in Eastern DFC (1) (Demand and Technical)

No.	Section	Length (km)	Nos. of Detour Section	Detour section Length (km)	Ration of Detour (%)	The time when transport demands reaches equivalent to capacity	Reliability of Design	Difficulty of Construction (ROB to be replaced)	Necessary Provision in case that the section is not constructed
E-A1	Mugal. Sarai – Kanpur	322	1	26	7 %	2010	【Route Design】The detour route at Allahabad have to be examined and technical examination is needed for replacement of ROB and detour route at Meja Rd but it would be finalised within this year 【Station Yard Design】The draft design would be prepared within this year including Jeonathpur(West side of Mughal Sarai Jn) 【Important Bridge】 1. Ton River/Length 460m, 2. Januna River/Length 1,160m	Total Number of ROB: 2 Number of ROB whose replacement is difficult: 1 Jeonathpur (Adjointing canal. The finished ground of DFC will be raised)	Improvement of signal and station yard to strengthen the line capacity
EA-2	Kanpur – Khurja	388	5	127	33 %	2010	【Route Design】The detour routes at Kanpur, Etawah and Aligarh have to be examined but it would be finalised within this year. 【Station Yard Design】The draft design would be prepared within this year 【Important Bridge】 Non	Total Number of ROB: 0 Number of ROB whose replacement is difficult: 0	Improvement of signal and station yard to strengthen the line capacity
E-A3	Khurja - Dadri	46	0	0	0 %	2015	【Route Design】It would be finalised within this year 【Station Yard Design】The draft design would be prepared within this year 【Important Bridge】Non	Total Number of ROB: 0 Number of ROB whose replacement is difficult: 0	Improvement of signal and station yard to strengthen the line capacity
EB	Sonnagar - Mughal Sarai	127	0	0	0 %	2015	【Route Design】The deployment plan for Mughal Sarai J/S is crutial factor for route design of this section. Further review is needed. **【Station Yard Design】There are many existing line to be connected at Mughal Sarai J/S. This J/S is very complicated and route design is also related. Further survey and examination are required.** 【Important Bridge】Non	Total Number of ROB: 2 **Number of ROB whose replacement is difficult: 2** **1. Sasaram JN（Urban Area, Land acquisition problem）** **2. Bhabhua RD（Urban Area, Land acquisition problem）**	Improvement of signal and station yard to strengthen the line capacity
E-C1	Khurja - Kalanaur	242	3	50	21 %	1. 2010 (Existing Line in parallel) 2. 2015（Delhi – Ambala）	**【Route Design】**The detour route at Hapur, Meerut, Muzaffarnagar and Saharanpur have to be examined and there are 3 existing ROB to be replaced 【Station Yard Design】The draft design would be prepared between Mughal Sarai and Saharanpur within this year 【Important Bridge】 Non	Total Number of ROB: 2 Number of ROB whose replacement is difficult: 1 Muzaffar Nagar（Urban Area, Land acquisition problem）	Improvement of signal and station yard to strengthen the line capacity
E-C2	Kalanaur – Dhandarikal an	184	4	72	39 %	2010	**【Route Design】The urban area is progressing along the existing line. There are 4 ROBs and squatters are settled along the existing line. Hence the review including the study of another route is necessary.** 【Station Yard Design】The review is needed based on route plan review. 【Important Bridge】 1. Jamuna River/Length 490m, 2. Chaudah River/Length 100m, 3. Markanda River/Length 270m, 4. Tangri River/Length 180m	Total Number of ROB: 4 **Number of ROB whose replacement is difficult: 3** **1. Tandwal（Urban Area, Long span bridge）** **2. Khanna（Urban Area, Long span bridge）** **3. Dhandari Kalan（Urban Area, Long span bridge）**	Improvement of signal and station yard to strengthen the line capacity

Table 3-3 Evaluation of Project Feasibility at Each Section in Eastern DFC (2) (Environmental and Social Considerations)

No.	Section	Section Length (km)	Evaluation on Social Environmental Aspects			Evaluation on Natural Environmental Aspects	
			Land Acquisition Area for Railways and ROB and its difficulty	Location where the Resettlement is Required and its Scale (Number of Houses)	Location where the Resettlement of Squatter is Required and its Scale (Number of Houses)	Affected Natural Environment Wildlife Sanctuaries/Recorded Forests, etc.	Other Natural Environmental Issues
E-A1	Mugal. Sarai – Kanpur	322	Land Acquisition Area for ROB: 386 ha Land Acquisition Area for Railway: 693 ha The acquisition cost would be high because the most area is fertile agricultural land.	Parallel Section & Detour Section: Approx. 65 houses ROB: 2 houses at Ahraura Rd. RS 3 houses at Mirzapur RS 5 houses at Meja Rd RS	Parallel section: Approx. 25 houses	3 Reserved Forests within 1km from the existing line would be affected. The total length of the forests to be affected is approx. 16.5km in parallel to the existing railway. Trees along the exiting line would be affected by the project.	The affected trees are being studied using a sampling method in the site after identification of the affected forests. The DFC line would cross 2 important rivers, such as Tonse River and Yamuna River. The affected trees alongside the existing railway are being studied by analysis of the video data and other secondary data in addition to the field survey.
EA-2	Kanpur – Khurja	388	Land Acquisition Area for ROB: 316 ha Land Acquisition Area for Railway: 603 ha The land acquisition in this section is expected to be difficult like the urban area because the area is mostly fertile agricultural land.	Parallel Section & Detour Section: Approx. 450 houses ROB: None	None	5 Protected Forests within 1km from the existing line would be affected. The total length of the forests to be affected is approx. 2.7km in parallel to the existing railway. Trees along the exiting line would be affected by the project.	The affected trees of are being studied using a sampling method in the site after identification of the affected forests. The affected trees alongside the existing railway are being studied by analysis of the video data and other secondary data in addition to the field survey.
E-A3	Khurja - Dadri	46	Land Acquisition Area for ROB: 23 ha Land Acquisition Area for Railway：49ha The land acquisition is expected to be difficult because the section heavily built-up.	Parallel Section：Approx. 45 houses	None	Trees along the exiting line would be affected by the project.	The affected trees alongside the existing railway are being studied by analysis of the video data and other secondary data in addition to the field survey.
EB	Sonnagar - Mughal Sarai	127	Land Acquisition Area for ROB: 126 ha Land Acquisition Area for Railway： 221 ha The land acquisition of this section seems to be difficult like the urban area because the area is mostly fertile agricultural land.	Parallel Section: Approx. 45 houses Detour Section: The alignment information is not available.	None	Trees along the exiting line would be affected by the project.	The DFC line would cross Tonse River, an important river.
E-C1	Khurja - Kalanaur	242	Land Acquisition Area for ROB: 183 ha Land Acquisition Area for Railway：482ha The land acquisition in the urban area and near the road is expected to be difficult because the area consists of fertile agricultural land and industrial zones.	Parallel Section & Detour Section: Approx. 120 houses	None	1 Reserved Forest within 1km from the existing line would be affected. The total length of the forests to be affected is approx. 0.5km in parallel to the existing railway.	The affected trees are being studied using a sampling method in the site after identification of the affected forests. The DFC line would cross 4 important rivers such as Yamuna River, Chandah River, Markanda River and Tangri River.
E-C2	Kalanaur – Dhandarikalan	184	Land Acquisition Area for ROB: 136 ha Land Acquisition Area for Railway：306ha The land acquisition in the urban area and near the road is expected to be difficult because the area consists of fertile agricultural land and industrial zones.	Parallel Section & Detour Section: Approx. 260 houses	None	1 Reserved Forest within 1km from the existing line would be affected. The total length of the forests to be affected is approx. 0.5km in parallel to the existing railway.	No additional study will be conducted.

Note) The information in the table is based on the results of Environmental and Social Considerations Study (IEE level)

3.5 ESTABLISHING THE PHASED DEVELOPMENT SCENARIO

3.5.1 Comprehensive Evaluation of Project Feasibility of Each Section

To establish the phased development scenario, the characteristics related to the feasibility requirement in each section have been comprehensively evaluated and each section has been classified into following three categories.

Category A: Sections having commonality of stringent traffic situation in the short to mid-term future, and non existence of engineering and environmental issues in the near future that would undermine the implementation of the works

Category B: Sections having commonality of stringent traffic situation in the short to mid-term future, however its implementation is judged to be impossible in the immediate future due to existence of serious negative impact from the engineering and environmental aspect.

Category C: Sections having commonality of no serious traffic situation in the short to mid-term future,. .

The evaluation results in Western and Eastern DFC are summarised in Table 3-4 and Table 3-5.

It is noted that the grade separation of level crossing is excluded in the project.

Table 3-4 Classification of Each Section based on Feasibility Evaluation (Western DFC)

No.	Section	Section Length (km)	Category Evaluation Results	Major Points of Evaluation
W-A1	Dadri - Rewai	117	B	The benefit by expanding the line capacity in Delhi area would be significant, but it is impossible to start the construction in the near future as it will take long time to design the tunnel sections and improve existing ROB in TKD connection and to prepare EIA.
W-A2a	Rewari - Ajmer	290	A	The traffic demand would increase and reach the existing capacity in 2010. The DFC is constructed in parallel and adjacent to existing line along the lower-developed area in this section. If preliminary design is undertaken complying with guideline design, the technical and environmental obstacles can be avoided and EIA would be approved within this year.
W-A2b	Ajmer - Palanpur	368	A	Same as above WA-2a
W-A3	Palanpur - Ahmedabad	124	A	The traffic demand would increase and reach the existing capacity in 2010. 50% of the section is designed as detour route to avoid the urbanized area. If preliminary design is completed complying with guideline design, few technical/environmental obstacle are expected to encounter and EIA could be approved within this year
W-B1	Ahmedabad - Vadodara	136	A	The traffic demand would increase and reach the existing capacity in 2015. 100% of section is designed as detour route to avoid the urbanized area. If preliminary design is completed complying with guideline design, the technical/environmental obstacle are not expected to encounter and EIA could be approved within this year. However, attention is needed to design the long span bridge.
W-B2	Vadodara – Vasai Rd.	344	B	The traffic demand would increase and reach the existing capacity in 2015. There are 7 existing ROBs located in urban area whose replacement is difficult and a lot of squatters settled along the exiting line hence the construction of parallel and adjacent line is significantly difficult. Therefore the commencement of construction within coming years would be difficult or impossible.
W-B3	Vasai Rd. – JNPT	89	C	The existing line has enough line capacity up to 2025. The route study based on the accurate topographic information is required as this section has steep undulations. A tunnel might be necessary around Panvel. There are a lot of uncertainties for route design.

Table 3-5 Classification of Each Section based on Feasibility Evaluation (Eastern DFC)

No.	Section	Section Length (km)	Category Evaluation Results	Major Points of Evaluation
E-A1	Mugal. Sarai – Kanpur	322	A	The traffic demand would increase and reach the existing capacity in 2015. There is an existing ROB at Jeonathpur adjoining the canal with reverse siphon. The replacement should be duly designed considering the finished grade of DFC design. However this issue is not significantly critical. If preliminary designs of route and station yard are undertaken complying with guideline design, the technical/environmental obstacle are not expected to be encountered and EIA would be approved within this year.
E-A2	Kanpur – Khurja	388	A	The traffic demand would increase and reach the existing capacity in 2010. Five (5) detour routes are designed to avoid the urbanized area along the existing line hence no ROB will be required to be replaced. If preliminary designs of route and station yard are undertaken complying with guideline design, the technical/ environmental obstacle are not expected to encountered and EIA would be approved within this year.
E-A3	Khurja - Dadri	46	B	The traffic demand would increase and reach the existing capacity in 2020. The expansion of existing line is presently going on and the line capacity will strengthen due to the expansion. Accordingly the urgency of project implementation is not felt. It will be desirable to implement the project with Rewari-Dadri section in Western DFC to maximize the generated benefit.
E-B	Sonnagar - Mughal Sarai	127	C	The existing line has enough capacity up to 2030. After completion of the construction of Bridge at Son River, this section will improve to three line section and will have margin of line capacity. It is necessary to have additional survey and examination on complicated Mugal Sarai JS to implement the project in this section.
E-C1	Khurja - Kalanaur	242	B	The traffic demand would increase and reach the existing capacity in 2010. However alternative route, Khurja – Delhi - Ambala has enough capacity up to 2025. The urbanization along the existing line is progressing and there are 2 ROBs to be replaced. The review of route plan including detour route is needed. The planed DFC is single track in this line and the existing line has few passenger demands. Accordingly, providing the double track with both freight and passenger operation functions would be better than two separate dedicated single lines for freight and passenger. Further review is needed.
E-C2	Kalanaur – Dhandri Kalan	184	B	The traffic demand would increase and reach the existing capacity in 2015. The urbanization along the existing line is progressing and there are 3 large ROBs whose replacement would be difficult. The review of route design including detour route is needed.

3.5.2 Setting the Phased Development Scenario Consisting of Sections

Based on examination of each section undertaken above, the phased development scenario is set.

The sections were classified into 3 categories in previous section. Based on the classification, the constitution of sections which can individually generate project benefit is examined and the supplemental projects needed in each phase are identified.

For the development scenario, following three phases are considered.

Phase I-a Project: A particular section composed of smaller sections having commonality of stringent traffic situation in the short to mid-term future, and no existence of engineering and environmental issues (category A section) in the near future that would undermine the implementation of the works on the combined sections, and constitutes as an independently viable project that generate viable project effect. The Project is earmarked as a priority project since it was judged to be capable of bearing scrutiny by JBIC and other international lending agencies in the project appraisal process for the financial assistance.

Phase I-b Project: A particular section composed of smaller sections having commonality of stringent traffic situation in the short to mid-term future. However if it is contemplated to get the project financed by international lending agencies, the subject section has serious engineering and environmentally related obstacles, thus the implementation of the section is judged not eligible to be taken up by the international lending agencies in the immediate future (category B section). Even if the section is categorised as category C, if the effect of Project is expected to uplift effect to the Project, then the implementation of the section is taken up into the Project. The implementation of the sections in the Project can be done by self-financing and responsibility of the Government of India. However if the particular sections are assumed to be financed by international lending agencies, then maximum effort by the Indian Government will be required to eliminate the obstacles and address the issues. The Project I-b is assumed to be a project that will be implemented by the Indian Government taking immediate action to remove the obstacles, commence the preparation works on site by self –finance, and seek financial assistance from international lending agencies with approximately a two year lead time.

Phase II Project: A particular section composed of smaller sections having commonality of no serious traffic situation in the short to mid-term future, and is judged that its implementation can be deferred until the traffic demand exceeds its capacity. And sections which require reconsideration of the alignment over the whole stretch, and its immediate implementation is impossible.

The phased development scenario was established based on the aforementioned policy, the result of consideration of the evaluation result of the technical viability for project feasibility for each section as presented in table 3-3 and table 3-4.

(1) Establishing the phased development scenario for Western DFC

The phased development scenario for the Western DFC is presented in Table 3-5 and Figure 3-2.

Sections classified as category A in section 3.5.2 is an aggregate of consecutive sections which constitutes a single project. Thus, the Phase I-a Project is defined as the implementation of all projects coming under category A.

Sections classified as Category B are all adjoining to Phase I-a sections, and its implementation is expected to augment the Phase I-a project. Hence, the sections classified as category B is defined as Phase I-b Project. Sections between Vasai Rd and JNP are classified as category C. However since it was judged that the simultaneous implementation of this section would increase the project effect by the connection to JNP, the origin of the maximum demand, as well as due to the strong intention indicated by MOR for its early implementation. The Rewari-Dadri section was defined to be included in the Phase II Project since the finalisation of the basic design of the tunnel section and its environmental and social consideration study is likely to take approximately two years, and due to the requirement of reconsidering the alignment of the whole section.

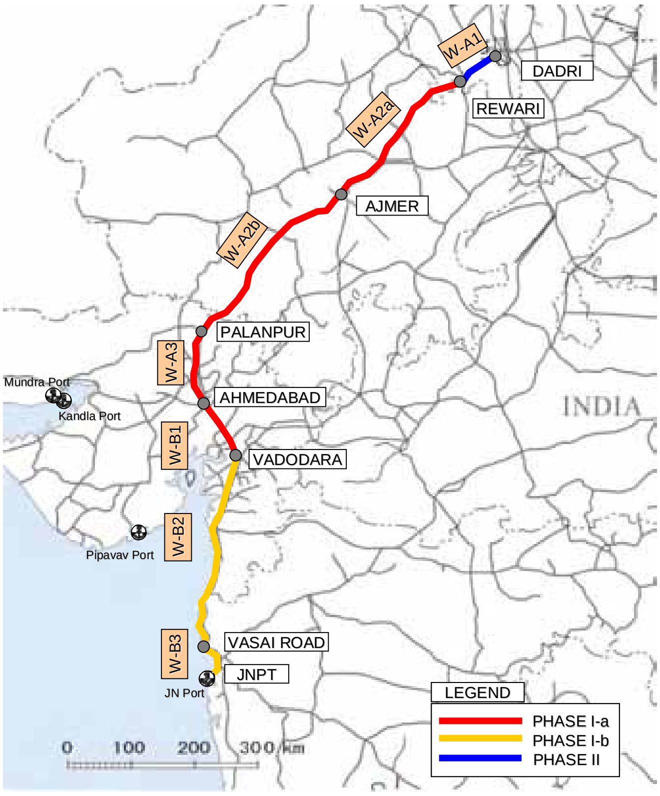


Figure 3-2 Phased Development Scenario (Western DFC)

Table 3-6 Phased Development Scenario (Western DFC)

<table>
<tr><td rowspan="2">Item</td><td colspan="7">Development Phase</td></tr>
<tr><td colspan="4">Phase I-a</td><td colspan="2">Phase I-b</td><td>Phase II</td></tr>
<tr><td>Development Section</td><td colspan="4">Rewari－Vadodara</td><td colspan="2">Vadodara – Vasai Rd.
and
Vasai Rd. – JNPT</td><td>Dadri – Rewari</td></tr>
<tr><td rowspan="2">Section Length</td><td>W-A2a
290km</td><td>W-A2b
368km</td><td>W-A3
124km</td><td>W-B1
136km</td><td>W-B2
344km</td><td>W-B3
89km</td><td>W-A1</td></tr>
<tr><td colspan="4">918km</td><td colspan="2">433km</td><td>117km</td></tr>
<tr><td>Assumed Duration for Construction</td><td colspan="4">6 years</td><td colspan="2">8 years</td><td>6 years</td></tr>
<tr><td>Commencement /Completion</td><td colspan="4">2008-09[1] / 2013-14</td><td colspan="2">2008-09 / 2015-16</td><td>2010-11 / 2015-16</td></tr>
<tr><td>Reason for Selection of Section</td><td colspan="4">No significant engineering and environmental constraint on alignment of sections parallel and adjacent to existing lines and detour sections. Basic plan is likely to be fixed this fiscal year.</td><td colspan="2">Substantial numbers of ROB difficult to reconstruct. Requires reconsideration of alignment.</td><td>Subject section has a tunnel section and requires further study.</td></tr>
<tr><td>Expected Benefit by Development</td><td colspan="4">(1) Strengthening of the transport capacity of trunk line between Northern India including NCR and Gujarat where deep sea ports exist.
(2) Improvement of the freight train operation to/from JNP/Mumbai Port by detouring the bottlenecked Ahmedabad to Vadodara sections.</td><td colspan="2">(1) Improvement of transport capacity of section between Vadodara – Vasai Rd. where the traffic situation is most severely congested. Enhancement of freight transport capacity between JN Port, Mumbai and NCR.
(2) Direct connection of Western DFC to JN Port.</td><td>(1) Improvement to the logistic network in NCR as the DFC is connected to the existing ICD of TKD and Dadri.</td></tr>
<tr><td>Necessary Supplemental Projects and Conditions to be met for realisation of Project</td><td colspan="4"><u>Supplemental Projects</u>
(1) Construction of a new ICDs between Rewari and Delhi is required as the DFC is not directly connected to existing major ICD (TKD, Dadri) in Phase I-a. (ICD construction is included in scope of this study due to its importance)
(2) Related to above (1), electrification between Rewari - Brar Square/ Patel Nagar is needed.
(3) Shortcut Route between Delhi Cantt.-Brar Square to connect ICD (TDK, Dadri) via existing line.
(4) Strengthening of transport capacity by improvement of signal and station yard between Vadodara - Vasai Rd.
<u>Conditions to be met for realisation of Project</u>
(1) Allocation of funds from Indian Government is required for land acquisition and construction works of the advanced initiated section.
(2) Decision to take up the works must be made before December 2007.
(3) Immediate discussion with road authorities regarding the reconstruction of the ROB is required.</td><td colspan="2"><u>Conditions to be met for realisation of Project</u>
(1) There exist a lot of existing ROBs in built-up areas where its reconstruction is considered to be difficult. Urgent review of engineering feasibility and reconstruction plan including the study on detour route is required.
(2) Since W-B2 and W-B3 sections are the heavily urbanised areas, land acquisition is considered to be difficult. Prompt action is required for achieving consensus among residents and expediting land acquisition.
(3) Route W-B3 requires further study based on the accurate topographic information since this section has steep undulations. Urgent topographic survey extending across the subject area and review of the alignment route is required.
(4) This Project is considered</td><td><u>Conditions to be met for realisation of Project</u>
(1) The tunnel section is located in Eco-Sensitive area and expected to have significant environmental impact to agricultural land. Early start of environmental survey is required for approval of EIA since approval process is considered to take time.
(2) Five ROBs exist along feeder line section to TKD where it is considered to be difficult for its reconstruction. Further study is required to minimise the number of reconstruction of ROBs, and consideration of plan to improve the</td></tr>
</table>

[1] 2008 – 2009 indicate Fiscal Year 2008

Item	Development Phase		
	Phase I-a	Phase I-b	Phase II
Development Section	Rewari－Vadodara	Vadodara – Vasai Rd. and Vasai Rd. – JNPT	Dadri – Rewari
	(4) Decision by Government of India is required for the selection of technology proposed by JICA Study Team. (5) Approval of the EIA for the alignment of the subject section is required by end of November 2007. (6) Continuous effort for consensus building among residents residing along alignment is required. (7) Immediate establishment of policy for construction of ICD is required.	to require sufficient funds and has engineering challenges which poses necessity of urgent consideration of securing funds from international lending agencies. (5) Assuming the involvement of international lending agencies, a timely execution and completion of an EIA study, that can bear the appraisal, is required.	existing lines.

(2) Setting the Phased Development Scenario for the Eastern DFC

The phased development scenario for Eastern DFC is presented in Table 3-7 and Figure 3-3.

Like Western DFC, the sections classified as category A in 3.5.2 are all continuous section and this composition can generate the benefit individually. Accordingly all of sections regarded as category A are set to form a part of Phase I-a project.

The sections classified as Category B in Eastern DFC are also all neighbouring of Phase I-a of the project. Hence the benefit to strengthen the Phase I-b project can be expected. Accordingly, all of sections regarded as category B to form a part of Phase I-b project.

Remaining sections in Eastern DFC are to be included as part of Phase II project.

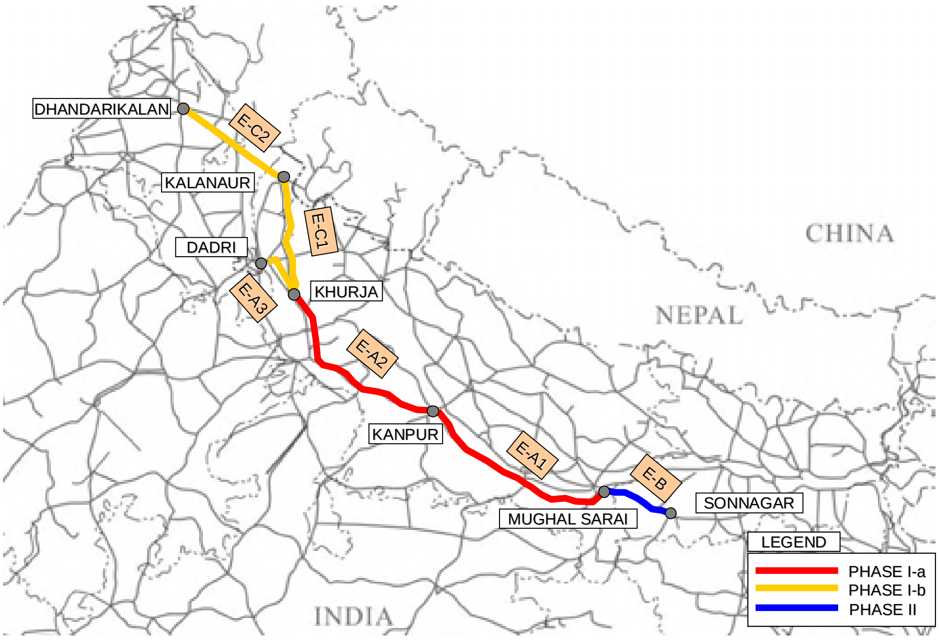


Figure 3-3 Phased Development Scenario (Eastern DFC)

Table 3-7 Phased Development Scenario (Eastern DFC)

<table>
<tr><td rowspan="2">Item</td><td colspan="6">Development Phase</td></tr>
<tr><td colspan="2">Phase I-a</td><td colspan="3">Phase I-b</td><td>Phase II</td></tr>
<tr><td>Development Section</td><td colspan="2">Mughal Sarai－Khurja</td><td colspan="3">Khurja – Dadri
and
Khurja－Dhandori Kalan</td><td>Sonnagar
–
Mughal Sarai</td></tr>
<tr><td rowspan="2">Section Length</td><td>E-A1
322km</td><td>E-A2
388km</td><td>E-A3
46km</td><td>E-C1
242km</td><td>E-C2
184km</td><td>E-B</td></tr>
<tr><td colspan="2">710km</td><td colspan="3">472km</td><td>127km</td></tr>
<tr><td>Assumed Duration for Construction</td><td colspan="2">6 years</td><td colspan="3">8 years</td><td>6 years</td></tr>
<tr><td>Commencement /Completion</td><td colspan="2">2008-09[1] / 2013-14</td><td colspan="3">2008-09 / 2015-16</td><td>2010-11 / 2015-16</td></tr>
<tr><td>Reason for Selection of Section</td><td colspan="2">No significant engineering and environmental constraint on alignment of sections parallel and adjacent to existing lines and detour sections. Basic plan is likely to be fixed this fiscal year.</td><td colspan="3">Substantial numbers of ROBs considered as difficult to reconstruct exist between Khurja and D. Kalan which necessitate reconsideration of the alignment at some sections.</td><td>The traffic between this section is projected to become saturated in 2025, thus the implementation of the project of this section is considered to be not urgent.</td></tr>
<tr><td>Expected Benefit by Development</td><td colspan="2">Strengthening the transport capacity of entire eastern DFC by development of the sections of severe congestion.</td><td colspan="3">(1) Strengthening of the logistic system between the eastern and western DFC by providing direct connection to both corridors.
(2) To improve the congested traffic situation of NCR by providing a bypass route, and connection of the northern Indian region with the western/eastern areas by means of DFC.</td><td>(1) Connectivity to Sonnagar by completion of the development of Eastern DFC.</td></tr>
<tr><td>Necessary Supplemental Projects and Conditions to be met for realisation of Project</td><td colspan="2"><u>Supplemental Development Project</u>
(1) Improvement of layout of Mughal Sarai Station to allow bypass of existing Mughal Sarai station.
<u>Conditions to be met for realisation of Project</u>
Conditions (1) to (6) indicated in Phase I-a Project of Western DFC must be met.</td><td colspan="3"><u>Conditions to be met for realisation of Project</u>
(1) Conditions (1), (2), (4) and (5) indicated in Phase I-b Project of Western DFC must be met.</td><td><u>Conditions to be met for realisation of Project</u>
(1) Finalisation of planning of the track layout of Mughal Sarai Junction station, and commencement of the land acquisition negotiation with the land owners of the region.</td></tr>
</table>

(3) Conditions for the Realisation of the Phased Development Scenario

The proposed phased development scenario divides the DFC Project into three phases of Phase I-a, Phase I-b, and Phase II, and the whole Project is planned to be completed within eight years from the commencement in 2008-09. The plan prepared by the Government of India is to complete the DFC Project in five years starting the works from 2008 and completing in 2012. However the JST has proposed as a reasonable implementation programme in which the Project is divided into three phases and completed it in fifteen years. The proposed implementation programme was presented to the MOR and discussed by the JST. MOR showed a firm indication of intention as follows:

1) The duration of the overall Project need to be planned at the shortest duration to the maximum extent.

[1] 2008 – 2009 indicate Fiscal Year 2008

2) Sections which are having stringent situation in the short term future be funded by own funds of the Government of India, and works commenced in 2008-09.

3) The improvement works of the existing lines running parallel with the DFC are not implemented prior to the implementation of the DFC.

The eight year implementation period of the phased development scenario proposed in this report take into consideration the intention of the MOR indicated above. Hence, in order to realise the project implementation based on the phased development scenario, maximum effort is a prerequisite by the Government of India to eliminate the obstacles mentioned in this section.

The following presents the prerequisites to be met for the realisation of each of the development phase.

1) Prerequisites for the realisation of Phase I-a Project

a) Project Financing Issues:	a1. Official discussions between the Government of Japan and Government of India regarding Yen loan has started, however no discussions are being held with international lending agencies regarding financial assistance. The Phase I-a Project alone is a massive project which extends 1,600km, and the success of the project depends on the arrangement of financing with favourable terms. It is advised that the Government of India urgently deliberate the necessity of requesting financing from ADB or World Bank, and start with the specific discussions.
	a2. Immediate securing of self-financing for the cost of the works not eligible to be covered by loan from international lending agencies, and cost for those works that need advanced implementation by the Indian Government.
b) Engineering Issues	b1. To facilitate execution of project appraisal by the international lending agencies the following design activities need to be completed by December 2007: - Final Location Survey of the alignment of the DFC and the stations. - Preliminary design and flood analysis of each important bridge. - Preliminary design of junction stations
	b2. Urgent engineering survey and preliminary design for the ROBs that will replace the existing ROBs which are subject to reconstruction, and discussion regarding the design with the road authorities.
	b3. Urgent decision by the MOR for the technical options compared and proposed in the Study.
	b4. Urgent policy decision on the policy of MOR for the provision of the new ICD, located between Rewari and Dadri, which will be required for the commissioning of Phase I-a of Western DFC.
c) Environmental and	c1. The approval by MOR of the ESIMMS (a rapid EIA

Social Issues — level study) report prepared for each district by end of November 2007. The approval of the ESIMMS report for the portion of Project by Yen Loan is required 120 days prior to the Loan Agreement (L/A).

c2. MOR/DFCCIL take initiative, making continuous effort in carrying out public consultations to build consensus among the residents who have voiced dissent to the project as was identified in the results of the SHM.

2) Prerequisites for the realisation of Phase I-b Project

a) Project Financing Issues:

a1. The Phase I-b Project extends more than 900km, and has engineering challenges as well as environmental issues that complicates the implementation. The project cost is similar in size to Phase I-a Project. Similar to the reason given in Phase I-a, it is advised that the Government of India urgently deliberate the necessity of requesting financing from international lending agencies such as ADB and World Bank.

a2. Immediate securing of self-financing required for land acquisition and the cost of the works determined to be implemented by the Indian Government.

b) Engineering Issues

b1. Urgent engineering survey and preliminary design for the obstacles of the following items:

- Detailed site survey and careful study of engineering feasibility of the existing ROBs that are determined to be reconstructed, however which the works are determined to be extremely difficult.
- It is envisaged that the land acquisition of the subject section be difficult since it is situated in a heavily built-up area. The review of plan and the preliminary design of the station need to be prepared to minimise the scale of land acquisition and resettlement.

b2. In view of the above, a comparative study is urgently required between the DFC planned in parallel to the existing line and that of an alternative route established that avoids those sections, having many ROBs, and area where it is extremely built-up or populated. For this purpose the topographical survey is required to be carried out immediately.

c) Environmental and Social Issues

c1. This section mainly passes through the suburbs and fertile agricultural land, and the residents have voiced dissent in the stakeholder meetings. Since it is envisaged that it would not be easy to build consensus among the residents, thus continuous effort initiated by MOR/DFCCIL is required for the materialisation of the consensus building.

c2. In order to acquire fund for international lending agencies, MOR/DFCCIL need to take initiative to carry out a ESIMMS of JICA Study (a rapid EIA level study) in a timely manner that would withstand the appraisal.

3) Prerequisites for the realisation of Phase II Project

a) Project Financing Issues:	a1. It is advised that the Government of India urgently deliberate the necessity of requesting financing from international lending agencies such as ADB and World Bank, for the implementation of the Project.
b) Engineering Issues	b1. Urgent engineering survey and preliminary design for the obstacles of the following items: - The urgent reconsideration of the detour route for the tunnel section between Rewari-Dadri is advised. Also, the urgent execution of engineering survey and preliminary design for the tunnel section is advised. - The Mughal Sarai Junction Station is the origin of the Mughal Sarai-Sonnagar section and is conceived to be a vast facility which would require time to determine the design and discussion with the residents. Thus, the urgent commencement of the design work and coordination with the residents is advised.
c) Environmental and Social Issues	c1. There is a high possibility that the construction of the tunnel section between Dadri-Rewari will cause lowering the water level, thus site survey and thorough evaluation is required to assess its impact. The urgent execution of the natural environment survey is advised. c2. The timely execution and completion of the ESIMMS (rapid EIA level study) that withstand the appraisal need to be initiated by MOR/DFCCIL to secure finance from international lending agencies is required for the implementation of the Project.

For the establishment of the phased development scenario, the characteristics of each section with regard to the conditions for the feasibility of the project was grasped, as well as the defining of the subject project for each development phase of the development scenario, and identification of the sections that need to be consolidated into each development phase. The JST has previously separated the Project into three phases, and proposed the whole Project be implemented in fifteen years, on grounds that the existing lines be improved in advance of the DFC Project. In response to this proposition, MOR opined that 1) the DFC has been sanctioned to be implemented at the earliest and that a substantial extension cannot be permitted, and 2) the MOR has a policy in not carrying out the improvement works of the existing lines since the development of the DFC is prioritised. Considering the policy clarified by the MOR, the JST has established the policy for the phased development as follows:

Phase I-a Development Project: A Project composed of sections having commonality of stringent traffic situation in the short to mid-term future, and has non existence of engineering and environmental issues that would undermine the implementation of the works, and constitutes as a viable project that generate project effect independently, and considered to withstand the project appraisal by international lending agency.

Phase I-b Development Project: A Project composed of sections having commonality of stringent traffic situation in the short to mid-term future, however its implementation is judged to be impossible in the immediate future due to existence of serious difficulties from the engineering and environmental aspect, and likelihood of not being able to secure funds from international lending agency for its early implementation.

Phase II Development Project: A Project composed of sections having commonality of no serious traffic situation in the short to mid-term future, and it is judged that its implementation can be deferred until the traffic situation becomes stringent, as well as those sections that cannot immediately commence with the works due to necessity of review of its alignment.

The following table summarises the overall evaluation of the conditions of the feasibility of each section according to the aforementioned definitions:

3.6 CONSIDERATION OF APPLICABILITY OF PHASED DEVELOPMENT OF TECHNICAL OPTION

The sectional phased development was discussed in previous paragraphs. On the other hand, the technical option/specification can be similarly upgraded in phases based on the demand and the expected service level in the future. The examinations of phased development on several technical options applicable to DFC are discussed in the following paragraphs.

3.6.1 Container Transport System in Eastern Corridor

Most of the freight in Eastern Corridor is in bulk form and the number of containers is very small. There are no containers transported from ports in Eastern coast to Delhi area presently. Only very few domestic containers are transported by the existing line of Eastern corridor. The water depths of ports in Kolkata area are less than 10m hence the larger container ships can not call at these ports. Ocean containers are transported just only around Kolkata area not to distant locations such as Delhi through DFC.

DFC will have a link from Sonnagar to the deep sea ports in Kolkata area in the future, however the plan has not yet taken shape. Accordingly, it is reasonable to assume that the container transport demand in Eastern corridor will be low for the time being and thus the double stack container transport through the Eastern DFC is not needed from the view point of container demands at least for the short to medium future.

In this report, recommendation is made for the adoption of the single stack container transport for the Eastern DFC under the current circumstances where container demand is miniscule. By this, in order to minimize the number of ROB to be replaced. JST suggests that container demand should be reviewed and double stack transport should be examined when the deep sea ports plan is materialized and actual construction is commenced.

3.6.2 Station Yard Plan

Junction Stations (JS) are planned to link the DFC and existing lines. According to the conceptual layout drawing of the PETS-II report, the connection lines from the JS to existing lines are designed as clover-shaped grade-separated-crossing structure or triangle lines which are similar to ramp in expressway. As a result, a huge facility is planned for the JS. The JST deduced the reason for applying the grade separated structure as to the necessity to operate frequent train operation. However, the cost for constructing the embankment and railway-over-bridge is envisaged to become extremely high since the approach ramp will be more than 2,000m due to the restricted gradient of 1/200 (0.5%) and securing the necessary height of railway-over-bridge over double stack railway. In this connection, JST recommends the adoption of the design policy for station yard that the size of station be designed in accordance to the expected demand. For the short to medium future, the traffic demands is expected to be still not large, hence the station can be designed to have at grade crossing equipped with a loop between both main tracks, or introduction of a switch back operation by provision of a shunting line could be applied.

The PETS-II proposes the clear standing room (CSR) as 1,500m, from the very first day of the commissioning of the DFC, based on the assumption that long trains will be operated. Since the necessity of operation of long trains is not justified from the projected demand, the JST proposes the application of the maximum effective length of 750m currently adopted on existing lines.

3.6.3 Improvement of Level Crossing

PETS-II proposed that all crossing be modified into grade separated structure in conjunction with the DFC Project. However, the following issues need to be taken into consideration and addressed before making the decision to go ahead with the implementation:

1) There are many level crossings in built-up areas where the grade separation works are envisaged to be difficult.
2) Burden on non-motorised vehicles crossing the railway.
3) Time required to build consensus among local residents to approve the construction of the level crossing since the impact to the society may be significant.
4) Examination for consolidation of level crossings with due consideration of the road development plan.
5) Cost and scope allocation with road management authorities.

Accordingly, JST recommends that grade separation works of crossing be treated as a separate project and segregated from the DFC project where its implementation is done with annual budget of the Indian Government.

On sections parallel and adjacent to the existing line, a new double track will be provided in the DFC Project, which would result in the increase of time intercepted at the level crossing gates. Negative impact on the road traffic will arise if improvement is not made. Accordingly, automation of level crossing is proposed in the DFC project to shorten the time intercepted at the level crossing.

3.6.4 Electrification/Non Electrification in Western Corridor

In the Steering Committee meeting held in March 2007, it was agreed to apply the phased development scenario of train system for the Western corridor and the non-electrified traction system will be applied for the time being and after verifying the reliability and safety of double stack (DS) container operation on electrified traction system, that system will be applied. In this connection, JST visited China in April 2007 and studied actual operation of DS container operation under electrified traction system and confirmed that well type wagon system has been already prevalent and verified in China. Subsequently, JST examined the comparison study of container transport types (See *Chapter 5, paragraph 5.2*). As a result, the stability of double stack operation utilising flat-type wagons are not proven and, it was confirmed that double stack container operation utilising well-type wagon has ascendancy in economical terms as well as meeting the traffic demand. Accordingly, JST recommends that electrified traction be applied from Phase I-a with provision of application of well type wagon in the future.

The main transport requirement in Western corridor is container transport from JNP and Delhi. Presently the containers are transported by single stack on electrified line between JNP to Delhi metropolitan area. However, since the Phase I-a Project does not include the section connecting to JNP, the transport system after the implementation of Phase I-a remains unchanged from present condition, i.e. single-stack container operation under electrified traction system. If the non-electrified traction system is applied in Phase I-a, the trains from JNPT should be replaced and changed to diesel traction which has an economical disadvantage. Alternatively to use the electrified south route as at present will impact of DFC project adversely by running only half the forecast demand. Considering the main traffic demand is container from JNP, JST recommends electrified traction system be applied from Phase I-a for the Western DFC.

It should be noted that the wide range pantograph which can be fitted to a locomotive for two different heights of electrified lines for single and double stacks has been practically used, and hence the problem in train operation for the same locomotive is not anticipated between double stack section and single stack sections in the future.

CHAPTER 4
DEMAND FORECAST

CHAPTER 4 DEMAND FORECAST

4.1 INTRODUCTION

4.1.1 Transport Demand Outlook

Annual transport volume in net tonne km (NTK) of Indian Railways has increased at a growth rate of 7.1% per year from 2000-01, reached 439.6 billion NTK in 2005-06. Coal accounts for 44% of the total rail transport in tonne, being the most important commodity on the Eastern Corridor, and coal traffic is expected to continue increasing due to growth in power demand and development of new thermal power plants. International container, which accounts for 80% of the total container traffic by rail, is expected to increase firmly due to growth of foreign trade as the Indian economy strengthens ties with international economy. The result of the demand forecast of this Study shows that international container traffic at Indian ports will increase to eight times in 25 years from 2006-07, reaching 43 million TEUs in 2031-32. Although this growth is high, the estimated traffic is the same as the present traffic of international containers at U.S. ports (44 million TEUs in 2006), and is about half of that at Chinese ports (93 million TEUs in 2006).

4.1.2 Demand Forecast in Task-2

The demand forecast in Task-1 was updated in Task-2. The major change in the demand forecast model was an improvement for traffic assignment method using station-to-station Origin–Destination (O/D) and railway network data. Other updates and revisions are:

1) Update of the projection of coal traffic from PETS-I to PETS-II,
2) Revisions of Maharashtra’s and Gujarat’s share in container traffic,
3) Revisions of rail share at Gujarat’s ports, and
4) Revisions of commodity growth rates

The target year of the projection was changed in accordance with the review of the project schedule. Assuming that the first year of the operation of the DFC is the fiscal year 2013-14, the target years for the projection was set to every five years for 25 years from 2013-14 up to 2033-34. Since the terminal year of the projection was the year 2031-32 in Task 0 & 1, the projection in 2031-32 was used for the terminal year of 2033-34.

This Chapter does not include the contents such as socioeconomic analysis, passenger demand forecast, and a part freight demand forecast that was not changed in Task-2. Refer to *Volume 2 Task0&1 Chapter 6* for these contents.

4.1.3 Methodology of the Demand Forecast

(1) Overview of the Methodology

The future freight traffic by rail was projected, using the analysis in PETS-II and the Study of Intermodal Freight Transport Strategy (2006). The figure in the next page illustrates the overall work flow of the projection. Grey boxes in the figure indicate the revised procedure from Task-1.

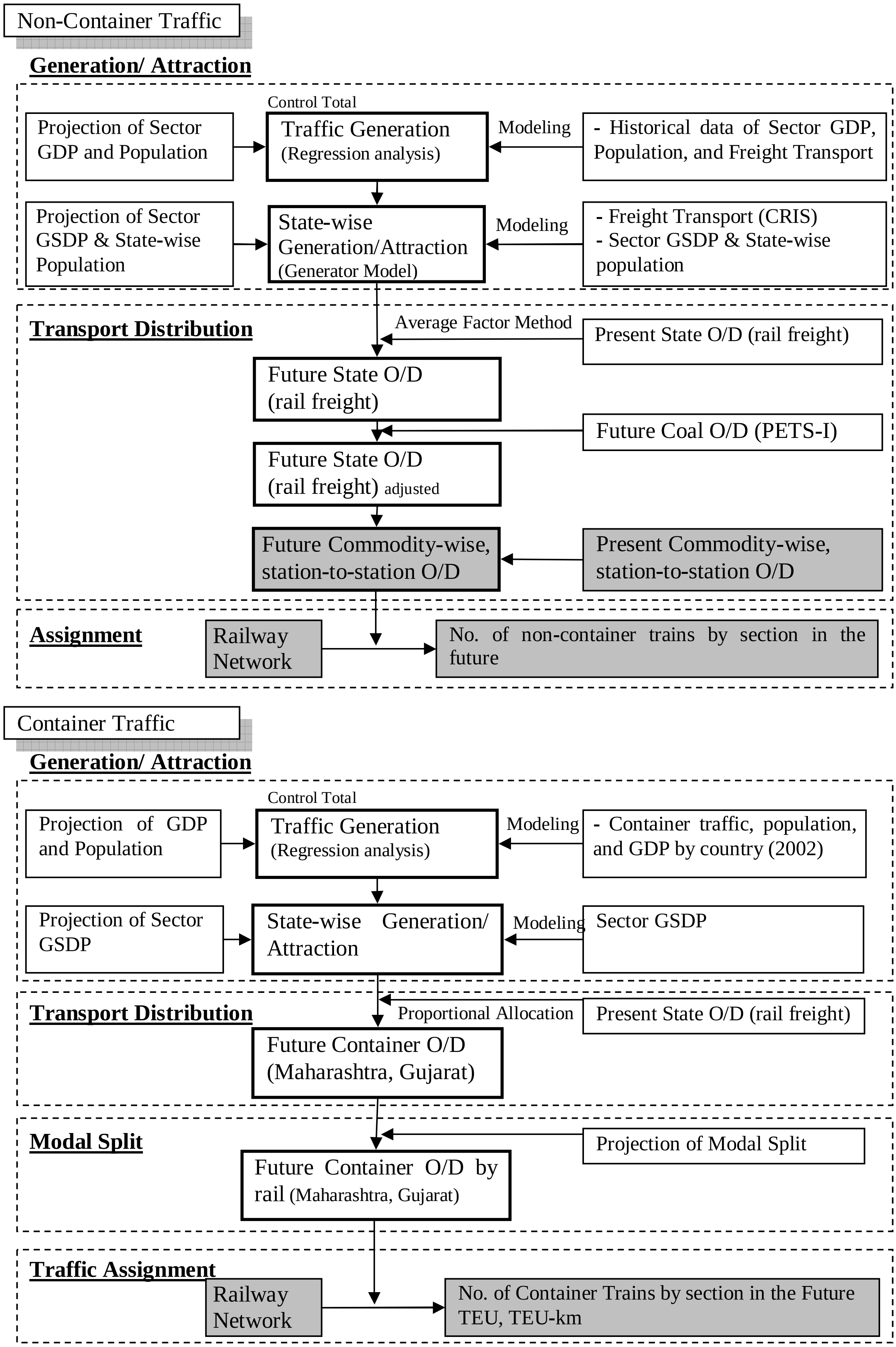


Figure 4-1 Flow of Demand Forecast of Freight Train in This Study

The major different points from PETS-II was the applied method for the commodity-wise growth rates, the container projection, and the additional projection of freight and passenger traffic on the existing rail for economic and financial analysis. PETS-II had directly assumed growth rates for commodity-wise traffic in all states, while this study had developed forecast models of rail traffic, applying sector-wise GDP and population of each state as explanatory variables, to estimate commodity-wise inter-state growth rates. Traffic assignment technique was used to estimate the section-wise traffic. The inter-state growth rates were applied to the present station-to-station O/D to estimate the future station-to-station O/D, which was assigned to railway network to compute the future traffic volume. Capacity constraint of the existing rails along the corridors was considered, and the traffic volume that could not be assigned to the railway network due to capacity constraint was computed.

Commodities were classified into coal, iron ore, iron & steel, cement, food grain, fertilizer, POL, container, and others. The projection by PETS-II was used for coal traffic forecast of the Eastern Corridor because the analysis of origin (coalfields) – destination (power houses) was proper.

(2) Station-to-Station O/D and Railway Network

Since the station-to-station O/D was considered to be necessary data for the traffic assignment, the train O/D of Centre for Rail Information Systems (CRIS) was aggregated. The stations in train O/D of CRIS were merged into 340 stations from 2,533 stations in order to make the station-to-station O/D. Due to the simplification, the present traffic for the projection worked out to be 53,500 million tonnes compared to the actual volume of 68,238 million tonnes. In order to assign station-to-station O/D to railway routes, a railway network data (497 links and 340 nodes) was prepared. Since the network for the traffic assignment was simplified, the total length of the network worked out 43,353km, which was about 70% of the actual route length of 63,332km.

	Route length	Tonnes	Tonne-km
Actual (2005-06)[/1]	63,333 km	682.38 million	441.76 billion
Model in this Study	43,353 km	535.04 million	326.79 billion

Source[/1] : Year book

(3) Traffic Assignment

Using the railway network data, the travel distance of each station-to-station O/D pair was computed, from which tonne-km was estimated for the traffic both on the existing rail and the DFC. The minimum path in distance was selected as the route of each O/D pair, except for coal transport. Link data was adjusted so that the assigned route could match the actual route of coal transport.

The number of passenger trains was considered for the existing railway along the both corridors, and it was assumed that the traffic that exceeds the line capacity of the existing lines would move to road. For other existing lines that were out of the both corridors, capacity constraints were not taken into account.

Figure 4-2 illustrates the work flow of the traffic assignment.

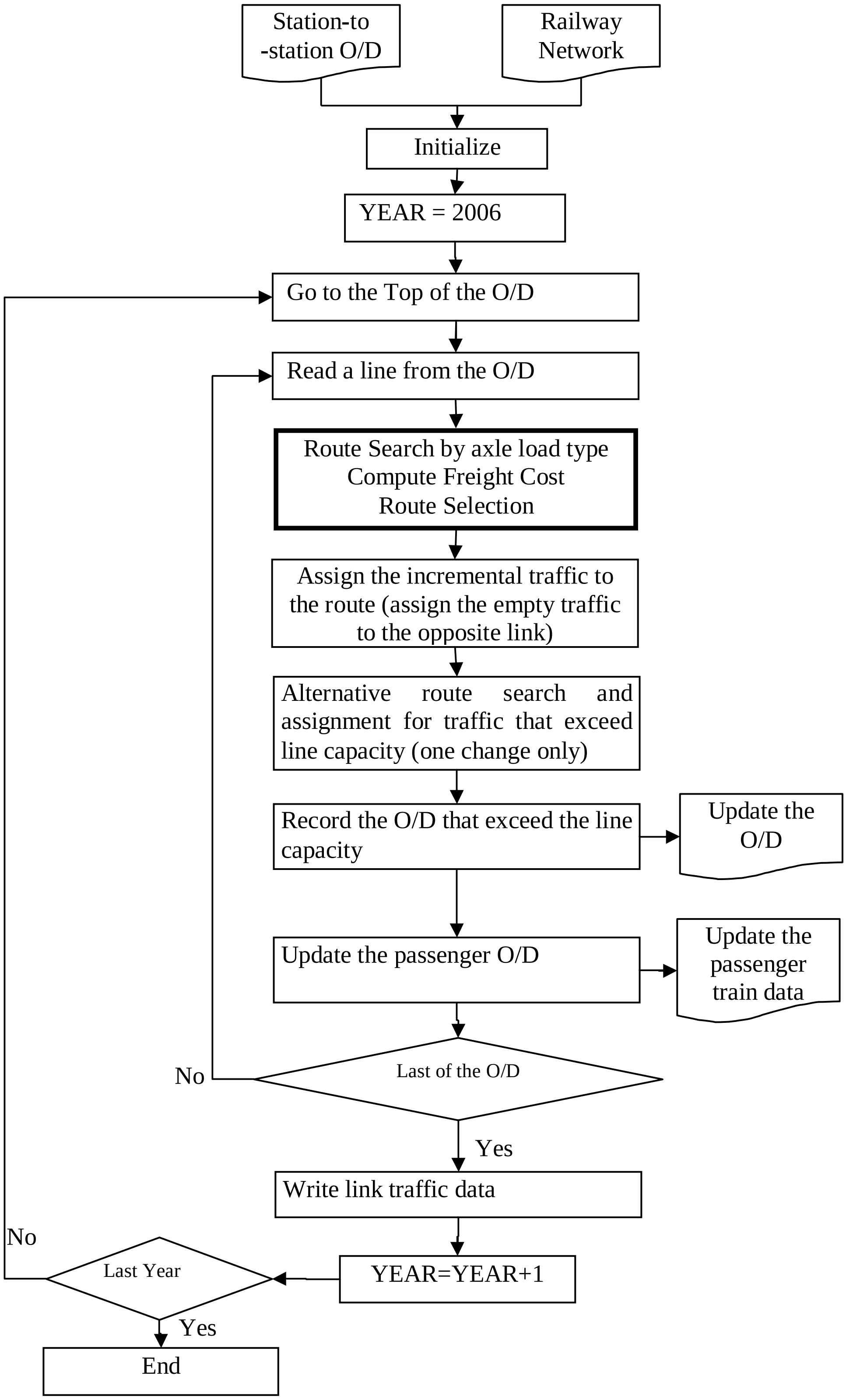


Figure 4-2 Flow of Traffic Assignment in This Study

4.2 DEMAND FORECAST OF FREIGHT TRANSPORT

4.2.1 Container Traffic

(1) Traffic Production of International Container

The Ministry of Shipping, Road Transport and Highways estimated[1] that container traffic would reach 15.1 million TEUs in 2013-14, increasing at Compound Annual Growth Rate (CAGR) of 18.31%.

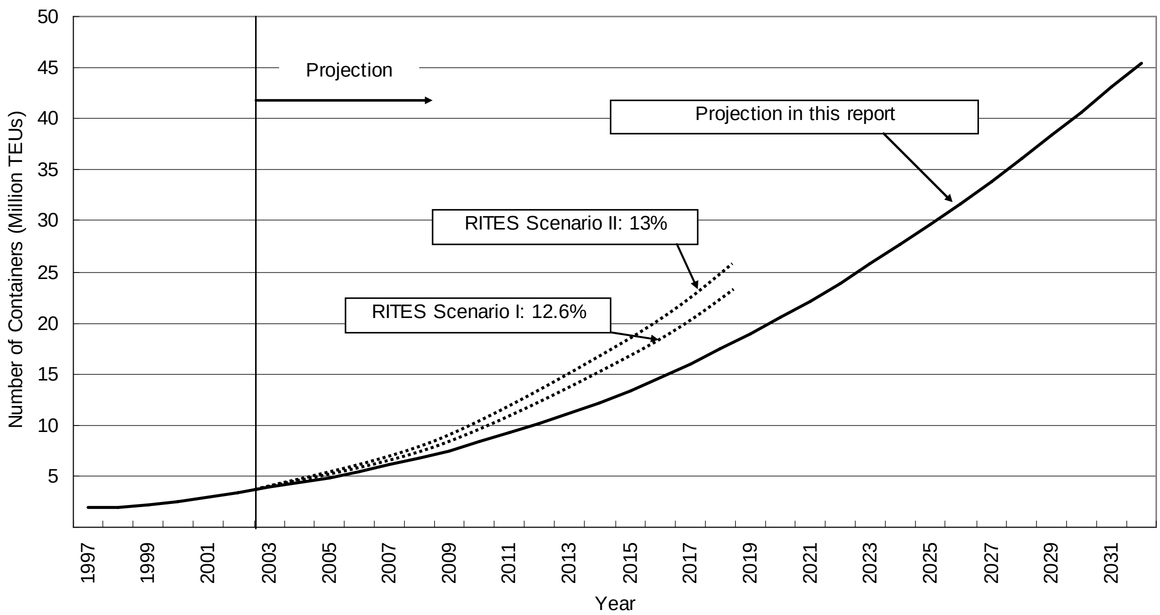
In this Study, a multiple linear regression analysis was carried out using population and GDP of 20 selected counties as its explanatory variables. The produced formula is:

$$CONT = 0.66 + 2.41^{-6} \times GDP + 0.0212 \times Pop \ (\mathrm{r}^2 = 0.96)$$

where, CONT = container throughput in million tonne per year
GDP = nominal gross domestic product in million US dollars
POP = population in million

Applying the estimated GDP and population of India in 2050 to the formula, CAGR up to 2050 was computed, and CAGR's of intermediate years were interpolated so that the growth curve connects the present traffic volume. Figure 4-3 shows the result.

It was projected that the throughput of export and import of container traffic would reach 221.5 million TEUs in the year 2021-22 and 430.5 million TEUs in the year 2031-32. The CAGR was calculated to be 10.1% from 2003 to 2021, and 6.9% from 2021 to 2031. This growth rate is lower than that assumed in PETS-II (12.6% and 13%).



Source: Study on Development of Intermodal Freight Transport Strategy, Final Report

Figure 4-3 Projection of Container Throughput at All Indian Ports

[1] "National Maritime Development Plan, 2005"

(2) Generation and Attraction of International Container

To allocate the total throughput from each state, a linear regression analysis was carried out using the statistics of state-wise container traffic (14 ports in total) and NSDP of secondary sector as its explanatory variable. The produced formula is:

CONT = –230.6 + 0.000287×GSDP (r^2 = 0.93)
Where, CONT: container traffic by state ('000TEUs/year),
GSDP: Gross State Domestic Product (100,000 Rupees)

Applying the future state production, state-wise container traffic in 2031-32 was estimated as shown in Table 4-1. It was projected that container traffic in Maharashtra, where J.N.Port is located, would reach 15.3 million TEUs in the year 2031-32, and that in Gujarat, where Mundra and other new ports are located, would reach 13.4 million TEUs in 2031-32. The shares of each state in intermediate years were calculated by interpolating the share in 2031-32. Note that these containers would be transported not only by rail but also by road and through coastal shipping.

Table 4-1 Projection of Container Throughput

Unit: '000 TEU

Year	Maharashtra		Gujarat		India
	Traffic	Share	Traffic	Share	Traffic
2011-12	5,236	57.0	919	10.0	9,187
2016-17	7,563	51.6	2,238	15.3	14,651
2021-22	10,244	46.3	4,552	20.6	22,149
2026-27	12,965	40.9	8,194	25.8	31,729
2031-32	15,283	35.5	13,389	35.1	43,052

Source: Projection by JICA Study Team

The Eastern Corridor between Delhi and Kolkata presently does not carry any international container traffic, as per PETS-II demand projection. Since the precondition of port location at Kolkata is not clear, this study also did not consider international container traffic on the Eastern Corridor.

(3) Modal Split of Container Transport

Rail share in land transport of international containers is the most indefinite part in demand forecast of this Study, as well as PETS-II. This Study developed a simple modal split model using the result of traffic surveys and estimated the rail share in international container at ports to be 35% for Maharashtra's ports, and 45% for Gujarat's ports. Since it is about 25% at present, the model shows 10-20% increase in rail share.

To increase the rail share, it is necessary to gain market share of long distance transport, because it is difficult to compete with road transport in the market of short distance. Therefore, if rail is already dominant in the market of long distance transport, it is difficult to further increase market share. In a meeting with MOR, it was suggested that rail share between Mumbai and Delhi is approximately 60%. On the other hand, the rail share of container for the section was roughly estimated to be 85%, from a small-scale traffic count survey at the state boarder of Haryana and Rajasthan on NH-8 in June 2007. If truck share is only 15% currently, increase in rail share by 10% will be difficult. However, it will be possible to achieve the share increase if the DFC can gain market share not only from FLC (Full container load cargo) but also from LCL (Less than container load cargo) that is transferred to non-container trucks at CFS and transported by the trucks. For this, an efficient intermodal system is inevitable. Assuming that necessary intermodal system is established, the rail share of 35% was applied for ports in Maharastra.

Rail share is influenced by the location of industry, as well as competition with road. For example, if industry around ports in Gujarat is largely developed, rail share would decrease because a larger number of container trips will have origin or destination near the ports. Although port-connecting road network in Gujarat is poor at present, it will be improved in the future. From this, the rail share of 35% was applied for ports in Gujarat, instead of 45%.

It was assumed that the rail share will gradually increase. Using these rail shares, container traffic by rail was projected as shown in Table 4-2.

Table 4-2 Projection of Container Traffic for 2021-22 and 2031-32

Year	Maharashtra		Gujarat		Total	
	Rail Traffic	Share	Rail Traffic	Share	Rail Traffic	Share
2004-05	647	25%	76	11.35	723	22.2%
2011-12	1,414	27%	138	15%	1,552	25.2%
2016-17	2,420	32%	448	20%	2,868	29.2%
2021-22	3,585	35%	1,593	35%	5,178	35%
2026-27	4,539	35%	2,868	35%	7,407	35%
2031-32	3,549	35%	4,684	35%	10,035	35%

Source: Projection by JICA Study Team
Note: * 90 TEU per train, 330 days per year

(4) Future ICD Traffic

The future traffic at ICDs was estimated by applying growth rate at ports to the existing O/D (port – ICD). It was assumed that the present origin-destination pattern of container traffic would be the same in the future. The ratio of the traffic at each ICD to that of each port (Mundra, Kandla, Pipavav) is assumed to be the same as the ratios of JNPT. The traffic projection in Delhi Area and Ludhiana are shown in the table below. Due to 8-fold growth for international container traffic at ports in 25 years with rise in railway share, the total traffic at ICDs was estimated to increase 12 – 13 times. As a result, container traffic in Delhi expected to increase from 0.5 million TEUs at present to 6 million TEUs in 2033-34. Since such concentration of a huge volume of container traffic to a place is unrealistic, it is expected that new locations of ICDs will emerge.

Table 4-3 ICD Traffic in Delhi Area and Ludhiana ('000 TEUs)

	2005-06	2013-14	2023-24	2033-34
Delhi Area	485	1,223	3,581	5,925
Ludhiana	113	254	861	1,530

Source: Projection by JICA Study Team

(5) Domestic Container

Domestic containers account for 20% of the total container traffic in India. Although the increase in domestic containers is gradual as compared with that of international container, the traffic increased by 6.4% in 2005-06 and reached 374,000 TEUs. It is expected that domestic container traffic will continue to grow. This study did not estimate the future demand in domestic containers, but assumed a moderate annual growth rate of 2% same as in PETS-II.

Table 4-4 Container Transport by Rail ('000 TEUs)

	2003-04	2004-05	2005-06
Domestic Container	350	351	374
International Container	1,252	1,376	1,557
Total	1,602	1,728	1,931

Source: MOR

4.2.2 Coal Transport Demand

(1) Coal demand

Coal production has increased at a CAGR of 5% for the last five years (lignite excluded; 1999-00 – 2004-05, Economic Survey of India, 2005-06). Coal demand in 2004-05, which was assessed by Planning Commission, was 436.46 million tonne. The 10th Plan estimates that yearly coal demand would increase 460.5 million tonne in 2006-07 to 620 in 2011-12. Based on this, the annual growth rate from 2004-05 to 2011-12 was computed to be 5.1%.

Core sector of coal consumer consists of power, steel, cement, defence, and fertilizer. Power sector is the largest consumer of coal in the core sector. Indian Railways carried 294.25 million tonne of coal in 2005-06. Coal transport from coal fields to thermal power plants by rail accounts for 75% of the total coal transported by rail. Of the total installed power generation capacity at 127,673 MW, coal-fired thermal units account for 68,199 MW (54.2%). Sine coal is the dominant commodity in the Eastern Corridor, coal for thermal power plants in the Eastern Corridor was assessed separately from other commodities.

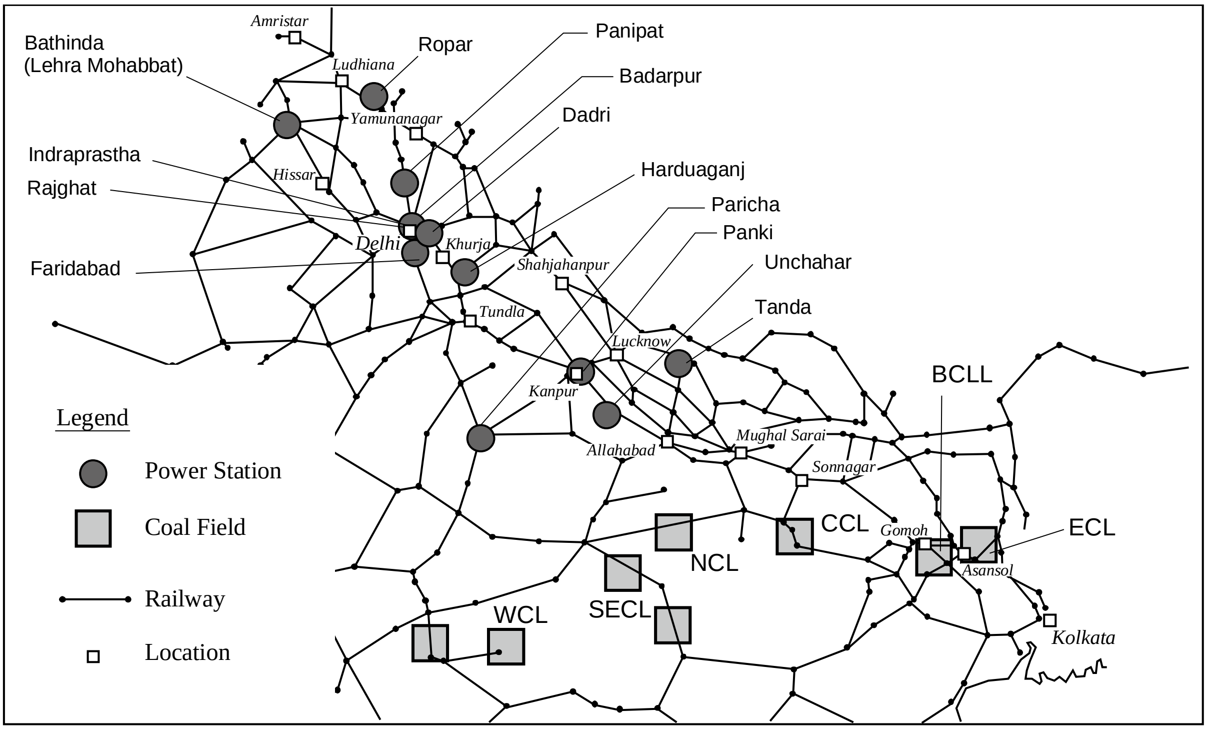
(2) Thermal Power Stations

Major thermal power plants which consume a huge amount of coal that is transported by rail were identified from the train O/D table provided by CRIS. Table 4-5 shows the list of the thermal power plants relating to the Eastern Corridor. Since the base year of the projection is 2004-05 in this Study, coal demand from new thermal power stations commissioned after March 2005 are not counted in the present demand but are regarded as the future demand.

Table 4-5 List of Thermal Power Stations

State	Owner	Name	Capacity (MW)
Delhi	Indraprastha Power Generation Co. Ltd. (IPGCL)	Indraprastha	237.5
		Rajghat	135
	National Thermal Power Plant Co. Ltd. (NTPC)	Badarpur	720
Haryana	Haryana Power Generation Co. Ltd. (HPGCL)	Faridabad	180
		Panipat	860
Punjab	Punjab State Electricity Board (PSEB)	Bhatinda	440
		Guru Har Govind Stage I (Lehra Mohabbad, Bathinda)	420
		Roper	1260
Uttar Pradesh	Uttar Pradesh Rajya Vidyut Utpadan Nigam Ltd. (UPRVUNL)	Harduaganj	450
		Panki	472
		Paricha	640*1
	NTPC	Dadri	840
		Tanda	440
		Unchahar	1050*2

Source: Central Electricity Authority (www.cea.nic.in)
*1: including Extension Unit 3 & 4 (420MW), commissioned December 2006
*2: including Stage III (210MW), commissioned September 2006



Source: Elaborated by JICA Study Team from PETS-I, II

Figure 4-4 Location of Thermal Power Plants and Coal Fields

(3) Coal Movement along the Eastern Corridor

Figure 4-5 illustrates the locations of thermal power plants and coalfields. The coal fields relating to the Eastern Corridor are Eastern Coalfields Limited (ECL), Bharat Coking Coal Limited (BCCL), and Central Coalfields Limited (CCL). Coal trains from these coalfields enter into the DFC tracks at Sonnagar and go to power plants in Delhi and further to the northern areas. Although coal trains from other coalfields do not use the DFC route at present, they are expected to get into the DFC at Kanpur or Allahabad if the DFC is constructed, because the present route is almost saturated.

(4) Power Station Projects

There are a number of projects of capacity expansion and new construction of thermal power plants which will be commissioned in the period of 10th or 11th Plan as shown in Table 4-6. The extension projects at Yamunanagar, Harduaganj and Paricha are under construction. The total increase in plant capacity worked out to be 7,370MW, from which the annual coal consumption was computed to be 36.85 million tonne. It was assumed that 1000 MW plant would consume 5 million tonne of coal as mentioned in PETS- II.

Table 4-6 New Power Plants and Coal Demand in the Period of 10th and 11th Plan

Owner	State	Name	Capacity MW	Start by
PSEB	Punjab	Guru Hargobind Stage II (Bhatinda)	500	May 2007
HPGCL	Haryana	Yamunanagar Unit 1 & 2	600	March 2008*1
UPRVUNL	UP	Harduaganj Unit 5 & 6	2×250	N.A.
UPRVUNL	UP	Paricha – Units 5 & 6	500	N.A.
NTPC	UP	NCPP Dadri Stage -II	490	2009-10
Rosa Power Supply Co. Ltd.	UP	Rosa Thermal Power Plant*2 (Shahjahanpur)	600	2010
NTPC	UP	Tanda extension	500	N.A.
NTPC	Delhi	Badarpur	2×490	2010
GVK Power Ltd.	Punjab	Goindwal Thermal Plant (Amrister)	2×250	March 2009
HPGCL	Haryana	Hissar Thermal Plant (near Barwala)	2×600	N.A.
Tata Powr Ltd.	UP	Chola (near Khuja)	2×500	April 2011
Total			7,370	

Source: PETS-II, JICA Study Team

PETS-II estimated coal traffic in 2011-12 from the projects of power houses as shown in Table below. Note that the traffic volume in 2005-06 was calculated from the train O/D of CRIS by the JICA Study Team, which differs a little from that of PETS-II.

Table 4-7 Coal Transport on the Eastern Corridor (2011-12)

Powerhouse	2005-06					2011-12				
	ECL	BCCL	CCL	NCL/ SECL	Total	ECL	BCCL	CCL	NCL/ SECL	Total
Badarpur	0.55	0.09	2.82		3.46	1.70	0.15	5.15		7.00
Batinda	0.13	0.14	1.19	0.29	1.75	0.75	0.10	1.40	0.30	2.55
Dadri	0.17		1.86		2.03	0.50	6.15			6.65
IP/Rajghat				0.21	0.21				1.92	1.92
Faridabad			0.70		0.70			0.83		0.83
Feroze Gandhi	0.48	0.61	1.80		2.89	0.48	0.52	3.94		4.94
Lehra Mohabbad	0.50		1.11		1.61	3.05		1.55		4.60
Panki	0.09	0.34	0.40		0.83	0.49	0.35	0.56		1.40
Harduaganj		0.18	0.28		0.46		0.50	4.13		4.63
Paricha	0.06	0.23	0.17	0.06	0.52	0.29	0.21	4.50	0.06	5.06
Rpoer		0.37	2.79	1.28	4.44		0.30	3.00	1.45	4.75
Tanda	0.36	1.92	0.25		2.53	0.66	0.36	4.06		5.08
Yamunanagar					0.00				3.00	3.00
Gindwal Sahib					0.00			3.00		3.00
Chola					0.00			2.50		2.50
Total	2.34	3.88	13.37	1.84	21.43	7.92	8.64	34.62	6.73	57.91

Source: Estimation from CRIS O/D by JICA Study Team (2004-05), PETS-II (2011-12)

After 11th Plan (2007-2012), there are capacity expansion plans at Yamunanagar (900MW), TATA Chola near Khurja (500MW), Nabha (1000MW) and Talwandi (1000MW). Besides these plans, plant-wise extension or construction plans for the Eastern Corridor are not so much clear at the moment. It is estimated that per capita consumption of electricity will rise to over 1,000 kWh/ year in 2012, which is still lower than 10,000 kWh/ year of per capita consumption in developed countries[1]. It is clear that 10th and 11th Plans are not enough to satisfy electricity demand of India. PETS-II cited Central Electricity Authority's prospect that capacity of coal base power plants would increase by 1000 MW in Punjab, Haryana, and Uttar Pradesh. Based on this, the additional capacity of new thermal power houses whose coal would be transported along the Eastern Corridor was assumed in PETS-II as follows:

Table 4-8 Assumed Additional Capacity in the 12th and 13th Plans (MW)

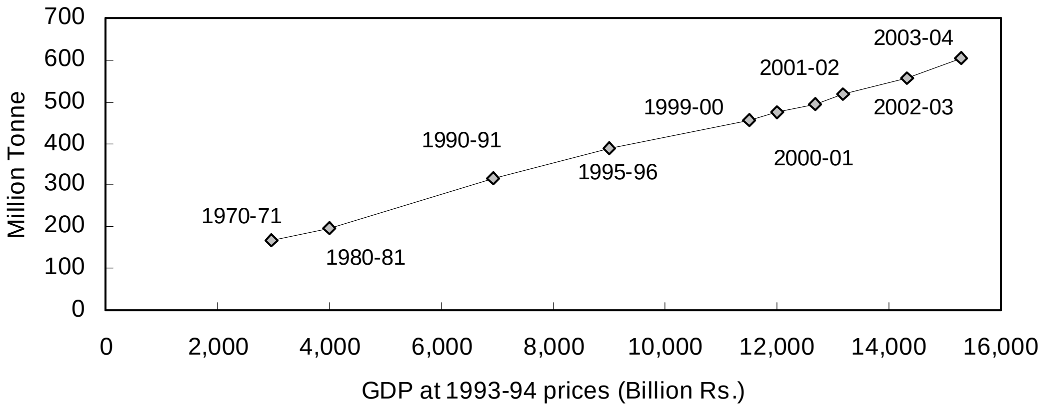
Powerhouse	2016-17					2021-22				
	ECL	BCCL	CCL	NCL/ SECL	Total	ECL	BCCL	CCL	NCL/ SECL	Total
Yamunanagar				1.50	1.50					0.00
Chola			2.50		2.50					0.00
Nabha				5.00	5.00					0.00
Talwandi				5.00	5.00					0.00
U.P.			2.50		2.50			5.00		5.00
Total	0.00	0.00	5.00	11.50	16.50	0.00	0.00	5.00	0.00	5.00

Source: PETS-II

4.2.3 Traffic Demand of Other Commodities

(1) Trip Production

Originating freight loading by Indian Railways has been correlating with GDP as shown in Figure 4-5. Correlation of originating freight by commodity type with population, GDP, and GDP of secondary sector was assessed by linear regression analysis using time series data that are shown in Table 4-9. The best formula was selected for each commodity type.



Source: CSO, IR
Note: Elaborated by JICA Study Team

Figure 4-5 Relation between GDP and Freight Traffic by Rail

1 Overview of Power Sector in India 2005, IndiaCore

Table 4-9 Time Series Data of Population, GDP, and Traffic Volume by Indian Railways

Year	1970-71	1980-81	1990-91	1995-96	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05
Population*1	541	679	839	928	1,001	1,019	1,037	1,055	1,073	1,091
GDP*2	2,963	4,011	6,929	8,996	11,484	11,986	12,679	13,184	14,305	15,294
Secondary	462	707	1,504	2,069	2,476	2,637	2,730	2,905	3,094	3,350
Coal*3	47.9	64.1	135.2	184.4	210.0	223.7	229.8	235.9	251.8	271.4
Ore	25.9	31.2	39.0	49.1	49.6	53.3	55.1	57.7	70.3	80.7
Iron & Steel	6.2	7.5	10.0	12.1	12.1	11.8	12.4	13.6	14.7	15.2
Cement	11.0	9.6	28.9	32.1	43.6	42.9	44.0	46.3	49.3	53.8
Foodgrains	15.1	18.3	25.4	24.9	31.1	26.7	32.8	45.6	44.3	46.5
Fertilizers	4.7	8.1	18.4	23.7	31.1	27.1	27.2	26.5	23.7	28.8
POL	8.9	15.0	25.0	28.9	34.3	36.3	35.6	34.1	32.0	32.0
Others	48.2	42.1	36.6	35.5	44.6	51.8	55.6	59.3	71.4	73.8
Total	167.9	195.9	318.4	390.7	456.4	473.5	492.5	518.7	557.4	602.1

Note: *1/ million; *2/ Rs. Billion (at 1993-94 prices); *3/ million tonne
Source: Central Statistics Organization (CSO), Indian Railways (IR)

Explanatory variables (GDP, GDP of secondary sector, and population) in the years 2021-22 and 2031-32 were projected in the previous section. Applying the explanatory variables to the formulae, the commodity–wise traffic volumes in the year 2021-22 and 2031-32 were computed. Table 4-10 shows the calculated compound annual growth rates (CAGRs) from years 2004-05 to 2031-32 and adopted explanatory variables for each commodity type.

Table 4-10 Commodity-wise Traffic Production (Million Tonne)

	Ore	Steel	Cement	Foodgrain	Fertilizer
2005-06*	82.8	15.6	55.5	47.8	29.7
2031-32	185.5	34.3	147.7	86.1	59.9
CAGR (%)	3.1%	3.1%	3.8%	2.3%	2.7%
Explanatory variable	Secondary GSDP			Population	GSDP

Source: Study on Development of Intermodal Freight Transport Strategy, Final Report

(2) Trip Generation and Attraction

The calculated freight generation by commodity was the total amount of originating freight by rail in India. State-wise generation and attraction were computed by generator method using the present generation and attraction data taken from the CRIS freight O/D. The formula of the computation is:

$$G_{mi} = C_m \times \frac{g_{mi} \times q_m}{\sum_n g_{ni} \times q_n}, \qquad A_{mi} = C_m \times \frac{a_{mi} \times q_m}{\sum_n a_{ni} \times q_n}$$

Where, G_{mi} = Generation for commodity type *m* in state *i*
A_{mi} = Attraction for commodity type *m* in state *i*
C_m = Total generation of all India for commodity type *m*
g_{mi} = Generator unit of generation for commodity type *m* in state *i*
a_{mi} = Generator unit of attraction for commodity type *m* in state *i*
q_m = Variable of the generator unit for commodity type *m*

(3) Coal Transport

The projected growth rate of coal is very much higher than other commodities. Although their correlation coefficients show good reliability of the models, the projected growth rate was higher than other projections such as TERI (The Energy and Resources Institute) and Work Energy Outlook. In this study, an annual growth rate of 2.4% was applied for coal transport except for coal transport from coal fields to powerhouses along the Eastern Corridor, which was projected in 4.2.2.

(4) POL Transport

With development of pipelines, the rail share in POL transport will continue to decrease. Therefore, the growth rate of POL was assumed to be zero in the projection.

(5) Trip Distribution

The future state O/D matrices (34 zones) were produced for each target year from the present O/D matrix that was elaborated from CRIS freight O/D and the state-wise generation & attraction of the target years.

Since the ratio of the secondary GSDP of each state to the secondary GDP of India was assumed to be the same in the future in the scenario analysis, growth rates of a commodity group between two states was computed to be the same when the commodity forecast model applied the secondary GSDP as its explanatory variable. Growth rates of such commodities are 3.1% of ore, 3.1% of steel, and 3.8% of cement. On the other hand, growth rates differed by the state pair for food grain, fertilizer, and other commodities because growth rates of their explanatory variables were estimated to differ by state. For these commodities, growth rates of inter-state traffic were computed from the future and present state O/Ds by applying fratar method.

(6) Modal Split

Modal split was not applied for non-container traffic projection because the commodity-wise generation models were developed so that it could estimate commodity generation by rail directly.

4.2.4 Station-to-Station O/D

The future Station-to-Station O/D was estimated from the present one according to the following preconditions:

1) For coal, the projection of the target year was directly applied.

2) For international container, the projection of the target year was directly applied.

3) For other commodities, inter-state commodity-wise growth rates were applied to the present Station-to-Station O/D.

The projected station-to-station O/D consists of 27,525 records. For traffic assignment, 2,533 stations are merged into 340 stations (traffic zones). Applying the 340 traffic zones, the station-to-station was integrated into an O/D which consists of 13,055 records.

4.3 DEMAND FORECAST SCENARIO

4.3.1 Scenario Setting

(1) Scenarios

The future transport volume was estimated for the following scenarios:

1) Without DFC Scenario (zero-option)
2) Base Scenario (Both DFCs, Eastern DFC only, and Western DFC only)
3) 5% GDP growth Scenario
4) Lower Rail Share Scenario:
   a) Rail share in container transport is constant (constant case).
   b) Rail share in container transport will not reach the target (share expansion delay case).
   c) Rail share in container transport will decrease (decrease case).
5) 5% GDP growth and Lower Rail Share Scenario

(2) Network

For the traffic assignment, rail network data were prepared for each target year as:

Corridor	Section	2013-14	2018-19	2023-24	2028-29	2033-34
Eastern	Dadri – Khurja		Y	Y	Y	Y
	Khurja – Mughal Sarai	Y	Y	Y	Y	Y
	Mughal Sarai – Sonnagar		Y	Y	Y	Y
	Khurja – Ludhiana		Y	Y	Y	Y
Western	Dadri – Rewari		Y	Y	Y	Y
	Rewari – Vadodara	Y	Y	Y	Y	Y
	Vadodara – JNPT		Y	Y	Y	Y

Note: Y means that the section is included in the rail network in the captioned year
Gray cells means that the section is not included.

4.3.2 Preconditions of the Traffic Assignment

The following are the preconditions for traffic assignment:

1) Container is transported by single-stack wagons.
2) Capacity constraint of the DFC is not considered.
3) All the non-container trains return as empty trains.
4) Tonne-km is estimated based on the model developed in this Study[1]

A high axle load (25 t) wagon can carry 1.28 times payload than the existing 20.3 t axle load wagon, which reduces the number of necessary trains. The following payload of a rake was applied for the calculation of the number of trains.

[1] Since stations are integrated and network is simplified, the estimated ton-kilometres is smaller than that of actual volume.

Table 4-11 Train Load

Commodity	Wagon	Payload	No. of Wagons	Train Load	Days
Coal	BCN	75.5 tonne	48	3,624 tonne	330
Steel	BOXN	77.0	40	3,080	330
Foodgrains	BCN	75.5	48	3,624	330
Fertilizer	BCN	75.5	48	3,624	250
Cement	BCN	75.5	48	3,624	300
Limestone	BOXN	77.0	58	4,466	330
Salt	BCN	75.5	48	3,642	300
Others*	-	-	-	2,500	330

Source: PETS-II, *: Assumption in this report

Line capacities of each link were set according to the following rules:

Line Condition	Capacity (Trains/day/direction)
Single track:	20
Double track of existing lines without automatic signalling system	50
Double track of existing line with automatic signalling system	110
New double track line (DFC)	140
Triple track of existing line(Mughal Sarai-Sonenagar)	150

4.3.3 Without DFC Scenario (Zero-Option)

(1) Without DFC with Capacity Constraints

This is the scenario when the DFC is not constructed and no railway project other than committed ones is implemented. This case assumes that the future traffic demand will emerge even if the DFC does not exist, and analyzes the situation when all the future traffic that can not be carried by rail is carried by road.

Traffic volume that exceeds rail capacity was estimated as shown in the table below.[1] Converting freight tons to the number of 10-ton trucks, the traffic worked out to be 2.18 million (6,000 per day) in 2013-14, 9.64 million (27,000 per day), and 16.84 million (47,000 per day).

Table 4-12 Traffic Demand on Highways in Without DFC Case

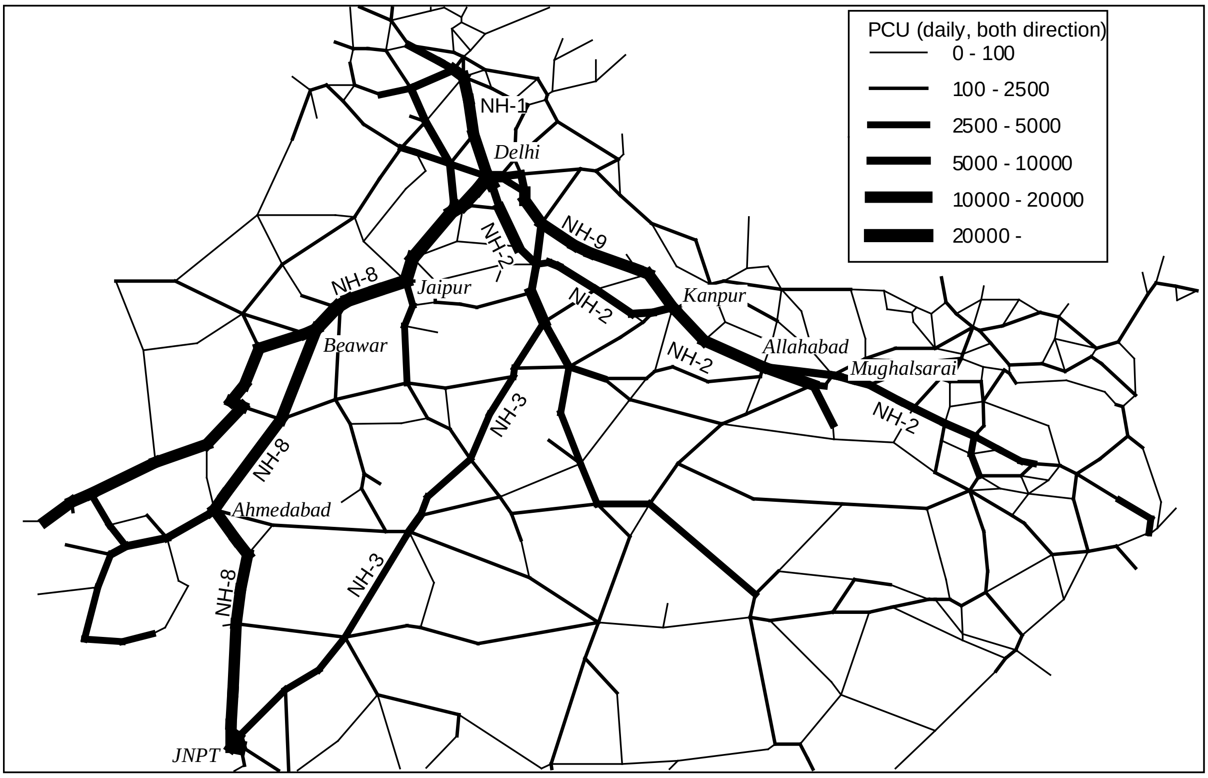
	2013-14	2018-19	2023-24	2028-29	2033-34	Unit
Freight	21.8	57.9	96.4	138.9	168.4	Million Tonne
	28.2	73.9	122.7	175.0	209.4	Billion Tonne-km
Passenger	2	5.5	11.4	23.4	34.1	Billion Passenger-km

The figure below illustrates traffic assignment of the overflow demand from railways to highways in 2033-34. It is expected that 4,300 container trucks, 1,300 of 10-tonne trucks, and 1,300 buses will add to the section of Mumbai – Ahmedabad – Jaipur on NH-8. In the section of Jaipur – Delhi on NH-8, additional traffic is 9,000 container trucks, 2,700 of 10-ton trucks, and 1,300 buses. In the Eastern Corridor, the additional 10-ton trucks are 3,600 on NH-2 and 7,000 on the section (Allahabad – Kanpur) where the number of overflow traffic is largest. These are heavy vehicles and the traffic volume doubles when they are converted into

[1] Since capacity constraint is not considered except for the East and West Corridors, the larger number of traffic will overflow from the existing lines. This study assumes capacity expansion projects will be carried out for those existing lines that are out of the corridors.

passenger car units (PCUs). For example, over 14,000 PCUs will be added to the section of Mumbai – Jaipur on NH8, which requires a 4-lane dedicated highway.

In addition to these, the traffic demand that is estimated to be carried by road in the demand forecast is to get into highways. Although 6-laning projects and expressway project will follow 4-laning projects, it is difficult to deal with the increase in traffic volume in zero-option unless highway development is accelerated.



Source: JICA Study Team

Figure 4-6 Traffic Assignment of Overflow Traffic on Highways

(2) Capacity Unconstraint Case in Without Scenario

In Task-1, the future traffic demand by rail was projected on the assumption that the line capacities of the existing rail are unlimited in order to carry out demand-capacity analyses and the alternative analysis. Since traffic demand was reviewed in Task-2, the traffic volume on the existing lines without capacity constraints was computed as shown in Table 4-13

Table 4-13 Future Traffic of the Existing Rail in Without Case, Capacity Unlimited

(No. of Trains per Day per Direction)

From	To	2006	2013	2018	2023	2028	2031
Bally Ghat	Saktigarh Jn	72	84	89	102	116	125
Saktigarh Jn	Barddhaman Jn	109	127	134	154	176	190
Barddhaman Jn	Khana Jn	81	95	100	115	131	141
Khana Jn	Andal Jn	63	74	79	91	103	111
Andal Jn	Asansol Jn	85	104	110	127	144	155
Asansol Jn	Sitarampur Jn	68	86	90	103	117	126
Sitarampur Jn	Dhanbad	48	61	65	73	81	86
Dhanbad	Gomoh	42	61	65	73	80	85
Gomoh	Koderma	46	68	73	82	90	95
Koderma	Manpur Jn	44	65	70	79	86	91
Manpur Jn	Gaya Jn	44	66	70	79	87	92
Gaya Jn	Sonnagar Jn	52	74	78	88	96	101
Sonnagar Jn	Sasaram	74	110	118	130	139	145
Sasaram	Mughal Sarai Jn	69	105	112	123	132	138
Mughal Sarai Jn	Chunar Jn	73	98	105	118	130	137
Chunar Jn	Mizapur	80	114	129	143	156	164
Mizapur	Chheoki	80	114	129	143	156	165
Chheoki	Allahabad	80	114	129	143	156	165
Allahabad	Fatehpur	72	104	116	127	137	144
Fatehpur	Prempur	73	105	118	128	139	146
Prempur	Kanpur Central Jn	74	106	119	129	140	147
Kanpur Central Jn	Bhaupur	98	132	146	160	174	184
Bhaupur	Etawah	92	126	140	154	168	178
Etawah	Shikohabad Jn	92	126	140	154	168	178
Shikohabad Jn	Firozabad	92	126	140	154	169	178
Firozabad	Tundla	92	126	140	154	169	178
Tundla	Barhan Jn	79	111	124	137	150	158
Barhan Jn	Hathras Ln	78	110	123	135	148	156
Hathras Ln	Daud Khan	78	110	123	135	148	156
Daud Khan	Aligarh Jn	78	110	123	135	148	156
Aligarh Jn	Khurja Jn	76	107	120	131	143	150
Khurja Jn	Dadri	77	101	111	122	134	141
Saharanpur Jn	Kalanaur	36	49	53	60	67	71
Kalanaur	Jagadhri	36	49	53	60	67	71
Jagadhri	Ambala Cantt Jn	35	45	47	54	60	65
Ambala Cantt Jn	Raipura Jn	84	105	114	132	149	159
Raipura Jn	Sirhind Jn	67	82	87	102	116	124
Sirhind Jn	Ludhiana Jn	51	65	70	84	97	105
Khurja Jn	Bulandshahr	11	20	22	24	25	26
Bulandshahr	Hapur Jn	11	16	17	19	20	21
Hapur Jn	Meerut City Jn	8	13	14	15	17	17
Meerut City Jn	Muzaffarnagar	5	9	10	10	11	11
Muzaffarnagar	Saharanpur Jn	20	27	29	32	36	38
New Delhi	Panipat Jn	68	82	90	104	117	126
Panipat Jn	Kurukshetra Jn	57	70	78	91	103	110
Kurukshetra Jn	Ambala Cantt Jn	57	69	77	89	100	107

From	To	2006	2013	2018	2023	2028	2031
JNPT	Panvel	12	32	43	70	86	94
Panvel	Diva Jn	37	61	73	104	124	135
Diva Jn	Vasai Road Jn	33	53	63	89	105	114
Vasai Road Jn	Virar	61	86	98	130	153	167
Virar	Dhahanu Road	71	98	111	145	171	186
Dhahanu Road	Valsad	67	94	106	140	165	179
Valsad	Udhna Jn	69	95	108	142	166	181
Udhna Jn	Gothangam	88	116	130	167	194	210
Gothangam	Bharuch Jn	78	105	118	153	178	193
Bharuch Jn	Makarpur	77	105	118	153	178	193
Makarpur	Vadodara Jn	77	105	118	153	178	193
Vadodara Jn	Anand Jn	60	70	75	87	99	107
Anand Jn	Ahmedabad	24	29	32	44	52	56
Ahmedabad	Chandlodiya Jn	63	73	77	90	103	112
Chandlodiya Jn	Mahesana Jn	20	24	26	30	35	38
Mahesana Jn	Palanpur Jn	26	30	32	40	46	50
Palanpur Jn	Jawai Bandh	27	33	37	60	82	97
Jawai Bandh	Marwar Jn	27	33	38	61	82	98
Marwar Jn	Haripur	25	31	35	56	77	92
Haripur	Ajmer Jn	21	26	30	51	71	85
Ajmer Jn	Phulera Jn	21	26	30	51	72	86
Phulera Jn	Jaipur Jn	35	42	47	71	93	109
Jaipur Jn	Bandikui Jn	22	28	31	51	70	84
Bandikui Jn	Alwar Jn	22	25	27	35	43	48
Alwar Jn	Rewari Jn	23	26	28	36	44	49
Rewari Jn	Garhi Harsaru	24	27	29	35	41	46
Phulera Jn	Ringas Jn	5	6	6	7	8	9
Ringas Jn	Rewari Jn	12	13	13	14	16	16
Vadodara Jn	Godhra Jn	47	67	77	103	120	130
Godhra Jn	Bhairongarh	64	87	99	133	157	170
Bhairongarh	Ratlam Jn	64	87	99	133	157	170
Ratlam Jn	Nagda Jn	65	88	99	133	157	170
Nagda Jn	Shamgarh	43	62	72	101	121	131
Shamgarh	Kota Jn	43	62	72	101	121	131
Kota Jn	Sawai Madhopur Jn	54	75	86	118	140	152
Gangapur City	Bayana Jn	51	72	83	114	136	149
Sawai Madhopur Jn	Gangapur City	51	72	83	114	136	149
Bayana Jn	Bharatpur Jn	34	53	63	93	113	124
Bharatpur Jn	Mathura Jn	34	53	64	102	130	148
Mathura Jn	Palwal	88	116	131	181	221	246
Palwal	Tuglakabad	98	127	143	194	236	263

Source: JICA Study Team

4.3.4 Base Scenario

(1) Eastern and Western DFC

This is the scenario when both the Eastern and Western DFCs are constructed according to the development scenario in Chapter 3. The result of the projection is summarized in Table 4-14.

It is estimated that the Eastern DFC will carry 68.7 million tons in 2013-14, 140.8 million tons after 10 years (more than two times larger), and 152.4 million tons after 20 years. For the Western DFC, it is estimated to carry 37.7 million tons including containers of 1.5 million TEUs in 2013-14, 96.2 million tons including 5.5 million TEUs after 10 years, and 140.4 million tons including 8.8 million TEUs after 20 years.

Some trains were found to use the both Eastern and Western DFC. This traffic is listed in *Volume 4 Technical Working Paper Task2, 4.*

(2) Eastern DFC Only and Western DFC Only

These are the cases, when only one, either the Eastern DFC is constructed or the case when only the Western DFC is constructed. These scenarios are necessary for economic and financial analysis for the Eastern DFC and the Western DFC. When the two DFCs are implemented, it is not simple to divide the overall benefit by the DFC project into the eastern and the western portions. To evaluate the Eastern DFC and the Western DFC individually, it is proper to assume the situation that only the Eastern DFC or the Western DFC is implemented. The results of the projection are summarized in *Volume 4 Technical Working Paper Task2, 4.*

If only the Eastern DFC is implemented, container traffic on the Eastern DFC would become larger than the case when the both DFCs are implemented, while non-container traffic would not change so much (only 1%-decrease in 2033-34). The increase in container traffic is the result of the route diversion of container traffic between Mumbai and Ludhiana from *the Western DFC – Rewari Jn. – Feeder Line* route to *Vadodara – Ratlam – Agra – Tundla – Khurja – Lhudiana* route.

If only the Western DFC is implemented, traffic on the Western DFC would become slightly smaller than the case when the both DFCs are implemented (only 1.6%-decrease in 2033-34).

(3) Traffic on Roads and the Existing Rail

For economic and financial analysis, traffic volume on the existing rail was also projected by using the railway network prepared by the JICA Study Team. The projected traffic on the existing rail does not represent the entire traffic on Indian Railways because the railway network was simplified for the projection in this Study. In the economic and financial analysis in this project, traffic in the Eastern and Western Corridor is important and the entire traffic volumes are not necessarily required. To estimate income from this project, only increase or decrease in traffic volume of the entire railway network is needed.

For economic analysis, traffic volume that will exceed line capacity of each railway line was computed and was assigned to the road network (also prepared by the JICA Study Team) to estimate tonne and tonne-kms of the traffic by road. The number of passenger trains that will exceed line capacity was also computed. Since passenger O/D was not incorporated into the demand forecast model in this Study, passenger-kms was estimated by allocating the exceeding passenger trains to a parallel road of each rail line.

The results are summarized in *Volume 4 Technical Working Paper Task2, 4.*

Table 4-14 Summary of Traffic Projection for Base Scenario

Eastern Corridor — Base Scenario (1TEU=12tonne)

		2013	2018	2023	2028	2031	
Ton (Bulk)		67.9	130.2	138.4	145.6	149.6	Million
TEU (Container)		70	162	194	222	237	'000
Total in Ton		68.7	132.1	140.8	148.2	152.4	Million
Ton-kms	on DFC	35.5	71.9	74.9	77.8	79.4	Billion
(Bulk)	on Feeder	45.1	78.2	83.6	88.6	91.4	
TEU-kms	on DFC	0.0	0.1	0.1	0.1	0.1	Billion
(Container)	on Feeder	0.1	0.1	0.1	0.1	0.1	
Ton-kms	on DFC	35.9	72.8	75.9	79.0	80.6	Billion
(Total)	on Feeder	45.8	78.9	84.3	89.5	92.3	
Train-kms	on DFC	19.0	38.4	40.3	42.2	43.2	Million
	on Feeder	27.4	47.4	50.9	54.3	56.1	

Western Corridor — Base Scenario (1TEU=12tonne)

		2013	2018	2023	2028	2031	
Ton (Bulk)		19.5	27.9	30.2	32.8	34.4	Million
TEU (Container)		1,516	3,554	5,502	7,516	8,831	'000
Total in Ton		37.7	70.6	96.2	123.0	140.4	Million
Ton-kms	on DFC	13.4	20.0	21.9	24.0	25.4	Billion
(Bulk)	on Feeder	16.7	20.1	21.5	23.1	24.2	
TEU-kms	on DFC	1.3	4.1	6.0	7.9	9.1	Billion
(Container)	on Feeder	0.8	0.6	1.2	1.8	2.2	
Ton-kms	on DFC	29.4	68.9	94.3	119.3	134.8	Billion
(Total)	on Feeder	26.8	27.6	35.5	44.7	51.1	
Train-kms	on DFC	25.1	60.6	83.7	106.5	120.6	Million
	on Feeder	22.0	22.3	29.3	37.5	43.2	

Road and Existing Rail — Base Scenario (1TEU=12tonne)

		2013	2018	2023	2028	2031	
Ton	on Existing Rail	483.9	494.1	561.9	636.6	683.8	Million
(Bulk)	on Road	0.2	1.2	3.6	10.2	17.2	
TEU	on Existing Rail	832	740	982	1,205	1,338	'000
(Container)	on Road	252	84	258	478	644	
Ton	on Existing Rail	493.9	503.0	573.7	651.0	699.9	Million
(Total)	on Road	3.3	2.2	6.7	16.0	24.9	
Ton-kms	on Existing Rail	302.9	279.4	316.8	356.6	381.3	Billion
(Bulk)	on Road	0.3	1.3	4.1	11.3	18.1	
TEU-kms	on Existing Rail	0.6	0.5	0.6	0.8	0.9	Billion
(Container)	on Road	0.3	0.1	0.2	0.4	0.5	
Ton-kms	on Existing Rail	309.8	285.3	324.5	366.0	391.7	Billion
(Total)	on Road	4.4	2.1	6.7	16.0	24.5	
Train-kms	on Existing Rail	99.9	92.0	105.3	119.1	127.7	Million

Note: Projection by the JICA Study Team
Traffic of the existing rail is based on the railway network data prepared by the JICA Study Team.
Therefore, the computed tonne or tonne-kms does not equal to that of entire IR network. See *4.1.3-(2)*.

4.3.5 5% GDP Growth Scenario

This is the scenario when the annual growth rate of GDP is 5% for 25 years, instead of 7% in the Base Scenario. GDP of this case will be as small as about 60% of that of the Base Scenario after 25 years. It is assumed that demand in coal at thermal power houses will be the same along the Eastern DFC. The difference in GDP growth rate affect commodity-wise growth rates and demand forecast of international container in the model of this Study, although their GDP elasticity is very small. The applied growth rates are:

Scenario	GDP	Coal	Steel	Iron Ore	Food-grain*	Fertilizer*	Cement
Base Scenario	7%	2.4%	3.06%	3.15%	2.29%	2.74%	3.84%
Lower GDP Growth Scenario	5%	2.0%	2.01%	2.06%	2.10%	2.54%	2.52%

Note: POL=0% and Others=2% for both scenario
* : Although the projection model for foodgrain and fertilizer is based on population, lower growth rates (multiplied by 5/7) were applied for this scenario to evaluate the impact of lower growth rates.

Container traffic demand in this scenario is:

Year	7%	5%
2006-07	5,437	5,437
2011-12	9,178 (11.0%)	9,093 (10.7%)
2016-17	14,651 (9.8%)	14,192 (9.3%)
2021-22	22,149 (8.6%)	20,800 (7.9%)
2026-27	31,729 (7.5%)	28,582 (6.6%)
2031-32	43,052 (6.3%)	36,796 (5.2%)

Note: inside of () is CAGR of five years from the previous reference year

The result shows that transport volume in this case (GDP growth rate = 5%) will be almost the same as that of the Base Scenario (7%). The difference is so small that the transport volume of the Western DFC is approximately 12% less than the Base Scenario in 2033-34.

[Eastern DFC (GDP growth rate = 5%)]

	2013-14	2023-24	2033-34	Unit
TEU /1	70	188	222	’000 TEUs
Total Tonne /2	68.0	136.9	145.8	Million tonne
Ratio to Base Case/3	0.99	0.97	0.96	

[Western DFC (GDP growth rate = 5%)]

	2013-14	2023-24	2033-34	Unit
TEU /1	1,508	5,092	7,596	’000 TEUs
Total Tonne /2	37.4	90.5	124.1	Million tonne
Ratio to Base Case/3	0.99	0.94	0.88	

/1: includes domestic containers (1 wagon=2 TEU)
/2: includes containers (1 TEU = 12 tonne)
/3: Ratio of total tonne of the case to that of the base case

In the case above, the number of TEUs in 2033-34 is as large as 86% of the Base Scenario. Although this is the result of cross-country analysis, it is relatively optimistic that container traffic is only 10% less than that of the Base Scenario while GDP is smaller by 40%. Considering this, another scenario was estimated, assuming that container demand is as small as GDP when the growth rate is 5%. The table below shows the result of this case for the Western DFC.

[Western DFC (GDP growth rate = 5%, Smaller container traffic volume)]

	2013-14	2023-24	2033-34	Unit
TEU /1	1,442	4,032	5,613	’000 TEUs
Total Tonne /2	36.6	77.8	100.3	Million tonne
Ratio to Base Case/3	0.97	0.80	0.71	

/1: includes domestic containers (1 wagon=2 TEU)
/2: includes containers (1 TEU = 12 tonne)
/3: Ratio of total tons of the case to that of the base case

4.3.6 Lower Rail Share Scenario

The DFC will significantly improve container transport in the Western Corridor, which will increase rail share in container transport. The target rail share was set to be 35% at ports in Maharashtra and Gujarat, while rail share is currently 25%. However, there are some risks for achieving the rail share. First, if the project delays or no capacity expansion project for the existing lines are carried out, Indian Railway would lose the market share. Second, if travel speed by road becomes faster by introducing the latest trucks or highway network expands rapidly by unforeseen road projects, the rail share would also decrease. Third, if necessary ICDs are not constructed or adequate intermodal system is not established, the target rail share would not be achieved. From above, a risk analysis is required based on scenario for rail share. The following cases are prepared and analyzed in this Study.

1) Base scenario: rail share will reach 35% which is computed from the model

2) Share Expansion Delay Case: growth in rail share is moderate and the share will reach 30% in Maharashtra and 23% in Gujarat.

3) Constant Case: rail share remains the present level.

4) Decrease Case: rail share continue to decrease, and reach 5% in the future

Yearly shares of each case are:

Rail Share of Base Case

	2004-05	2011-12	2016-17	2021-22	2026-27	2031-32
Maharashtra	25%	27%	32%	35%	35%	35%
Gujarat	11%	15%	20%	35%	35%	35%

Rail Share of Rail Share Constant Case

	2004-05	2011-12	2016-17	2021-22	2026-27	2031-32
Maharashtra	25%					
Gujarat	11%					

Rail Share of Share Expansion Delay Case

	2004-05	2011-12	2016-17	2021-22	2026-27	2031-32
Maharashtra	25%	20%	22.5%	25%	27.5%	30.0%
Gujarat	11%	12%	15%	18%	20%	23%

Note: It is assumed that rail share drops in the first construction stage.

Rail Share of Decrease Case (5% in the end)

	2004-05	2011-12	2016-17	2021-22	2026-27	2031-32
Maharashtra	25%	15%	12.5%	10%	7.5%	5%
Gujarat	11%	10%	8.8%	7.5%	6.3%	5%

The figure below illustrates the projection of traffic by rail at ports in Maharashtra and Gujarat according to the rail share scenario. Approximately, the traffic of the middle scenario and the constant scenario are 75% and 50% of the Base scenario, respectively. Even if rail share decreases to 5%, container traffic by rail itself will slightly increase.

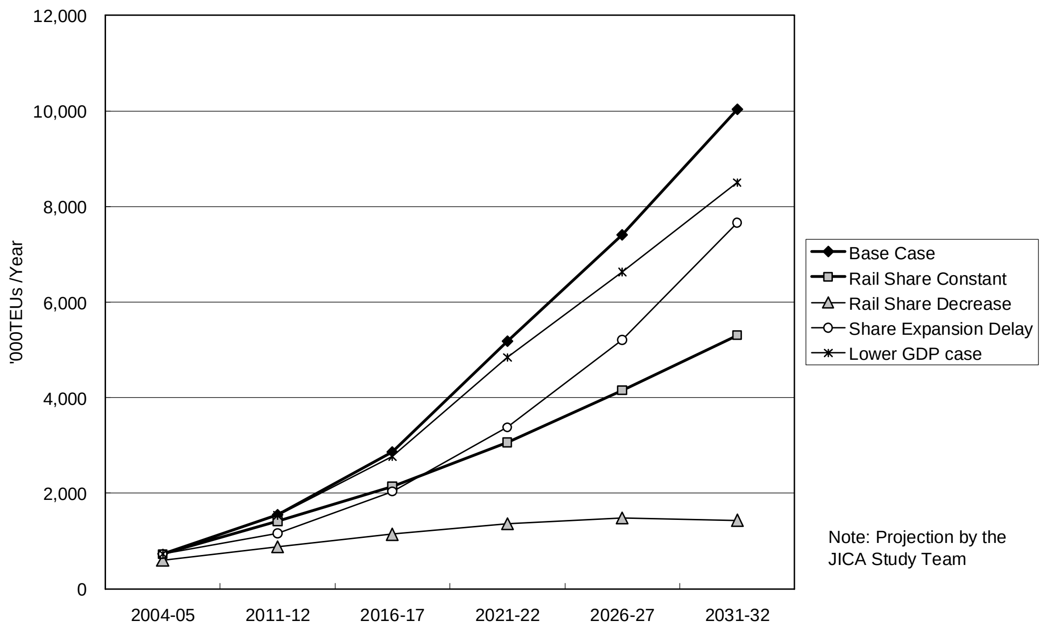


Figure 4-7 Projection of Container Traffic for Lower Rail Share Scenario

The table below shows the estimation of the traffic volume of the Western DFC in tonne by the scenarios (decrease case is excluded.). Since non-container commodities are included, the mid case is about 84% of the Base case, while the Constant case is about 2/3.

	2013-14	2023-24	2033-34	Unit
Base Case	37.7	96.2	140.4	Million tonne
Share Expansion Delay Case	35.0	75.9	116.3	Million tonne
Share Constant Case	36.1	69.7	92.4	Million tonne

4.3.7 5% GDP Growth and Share Constant

The table below shows the result of this scenario. Impact on the Eastern DFC is small, while the traffic volume in tonne of the Western DFC in this scenario will be about 60% of the Base Scenario in 2033-34.

[Eastern DFC (GDP growth rate = 5% and Rail share = constant)]

	2013-14	2023-24	2033-34	Unit
TEU	70	168	197	’000 TEUs
Total Tonne	68.0	136.7	145.5	Million tonne
Ratio to Base Case	0.99	0.97	0.95	

[Western DFC (GDP growth rate = 5% and Rail share = constant)]

	2013-14	2023-24	2033-34	Unit
TEU	1,353	3,047	4,165	’000 TEUs
Total Tonne	35.6	66.0	83.0	Million tonne
Ratio to Base Case	0.94	0.69	0.59	

4.4 DFC TRAFFIC

This section focuses on the numbers of trains on the DFC for base scenario, which was computed from the traffic assignment. O/D tables for the traffics that were assigned to the DFC are listed in *Volume 4 Technical Working Paper Task2, 4.*

4.4.1 Eastern Corridor

Section-wise traffic volume of the Eastern DFC is tabulated in Table 4-116 and Table 4-12. In the beginning, the number of trains per direction is 50 – 60 trains, which will increase to 70 – 90 trains in 10 years and 80 – 100 trains in 20 years. Coal trains account for about 70% in the direction to Delhi, while empty trains including deadhead trains of the coal trains account for 80% of the total number of trains in the opposite direction. However, the estimation is based on the assumption that all the non-container trains are returned as deadhead trains, and the number of empty trains might be smaller in actual operation. The number of trains in the section of Khurja – Ludhiana on the DFC will be as small as 20-30 trains per day per direction.

4.4.2 Western Corridor

Section-wise traffic volume of the Western DFC is tabulated in Table 4-18. The number of trains in Palanpur – Delhi section will become two times that of Mumbai – Palanpur section because ports in Gujarat will become the major origin and destination of international containers. The number of container trains will be 140 trains per day per direction in 20 years after the commencement of the operation. In the section of Palanpur - Phulera Jn., the number of trains, work out to be 180 trains per day per direction, will exceed the line capacity. This is because many non-container trains that connect Gujarat and the eastern states of India get into the DFC in the traffic assignment. Especially, fertilizer transport from plants such as IFFCO (Indian Farmers Fertilizer Cooperative Limited) contributes to about nine trains. The major route uses Palanpur – Phulera Jn. on the Western DFC, crossing between Phulera Jn. and Tundla on the existing railway, and enters into the Eastern DFC to the destinations in the east. Although this is rational route when the DFC exists, enough capacity is required between Phulera Jn. and Tundla.

4.4.3 Traffic at Junction Stations

Traffic volume between feeder lines and the DFC was computed for each junction stations. The results for all junction stations are summarized in *Volume 4 Technical Working Paper Task2, 4.* The table below shows the DFC – feeder traffic volume for major ports and ICD (Ludhiana).

Table 4-15 Traffic at Major Junction Stations

(Unit: No. of Trains per day per direction)

Terminal ports of feeder line	Direction of Origin or Destination	Junction Station	2013-14	2018-19	2023-24	2028-29	2033-34
Mundra and Kandla	Delhi	Palanpur Jn.	12	19	32	49	63
Pipavav	Delhi	Sabarmati Jn.	1	3	8	12	13
Dhandari Kalan ICD	Mumbai	Rewari Jn	16	20	28	36	42

Note: Projection by the JICA Study Team

Table 4-16 No. of Train on the Eastern DFC (Dadri - Sonnagar)

Sonnagar → Mughal Sarai → Khurja → Dadri

From Sonnagar To Dadri No. of Trains per Day

Year	Section	Coal	Iron/Steel	Others	Empty	Total
2013-14	Sonnagar - Mughalsarai					
	Mughalsarai - Allahabad	33.3	3.6	2.7	16.5	56.2
	Allahabad – Kanpur	43.5	3.5	2.1	8.7	57.8
	Kanpur(PMPR)-Kanpur(BPU)	42.0	3.9	3.4	9.7	58.9
	Kanpur – Tundla	42.0	3.9	3.8	13.5	63.1
	Tundla - Aligarh	40.1	2.3	4.9	4.4	51.8
	Alighar – Khurja	39.6	2.2	3.4	3.8	49.0
	Khurja – Dadri					
2018-19	Sonnagar - Mughalsarai	57.9	6.0	2.8	15.6	82.2
	Mughalsarai - Allahabad	42.9	5.8	3.3	21.2	73.2
	Allahabad – Kanpur	60.4	5.6	2.7	12.2	81.0
	Kanpur(PMPR)-Kanpur(BPU)	58.5	7.9	4.5	13.8	84.8
	Kanpur – Tundla	61.1	7.9	6.1	17.7	93.0
	Tundla - Aligarh	60.2	6.2	7.7	8.8	82.9
	Alighar – Khurja	59.6	6.2	5.9	8.1	79.7
	Khurja – Dadri	33.1	2.2	3.9	5.7	44.9
2023-24	Sonnagar - Mughalsarai	60.1	6.1	3.0	17.3	86.5
	Mughalsarai - Allahabad	44.3	6.0	3.4	23.6	77.3
	Allahabad – Kanpur	61.5	5.8	2.8	13.0	83.2
	Kanpur(PMPR)-Kanpur(BPU)	59.6	8.4	5.3	14.7	87.9
	Kanpur – Tundla	62.5	8.4	7.4	18.8	97.0
	Tundla - Aligarh	61.4	6.7	9.2	9.8	86.9
	Alighar – Khurja	60.7	6.7	7.1	9.0	83.4
	Khurja – Dadri	33.7	2.3	4.9	6.3	47.1
2028-29	Sonnagar - Mughalsarai	61.4	6.3	3.3	19.0	89.9
	Mughalsarai - Allahabad	45.3	6.1	3.7	26.1	81.1
	Allahabad – Kanpur	62.8	5.9	3.1	13.8	85.5
	Kanpur(PMPR)-Kanpur(BPU)	60.8	8.8	6.0	15.6	91.3
	Kanpur – Tundla	64.0	8.8	8.6	19.8	101.2
	Tundla - Aligarh	62.7	7.1	10.6	10.8	91.2
	Alighar – Khurja	61.9	7.1	8.2	9.9	87.1
	Khurja – Dadri	34.5	2.4	5.7	6.9	49.5
2033-34	Sonnagar - Mughalsarai	62.1	6.4	3.4	19.8	91.6
	Mughalsarai - Allahabad	45.8	6.2	3.7	27.5	83.2
	Allahabad – Kanpur	63.5	6.0	3.3	14.1	86.8
	Kanpur(PMPR)-Kanpur(BPU)	61.5	9.1	6.5	16.0	93.1
	Kanpur – Tundla	64.9	9.1	9.4	20.4	103.5
	Tundla - Aligarh	63.4	7.4	11.4	11.3	93.5
	Alighar – Khurja	62.6	7.3	9.0	10.3	89.2
	Khurja – Dadri	34.9	2.4	6.3	7.3	50.8

Note: Projection by JICA Study Team

Dadri → Khurja → Mugal Sarai → Sonnagar

From Dadri To Sonnagar No. of Trains per Day

Year	Section	Foodgrains	Fertilizer	Others	Empty	Total
2013-14	Sonnagar - Mughalsarai					
	Mughalsarai - Allahabad	2.5	1.9	12.8	39.2	56.5
	Allahabad – Kanpur	2.6	0.6	6.5	48.2	58.0
	Kanpur(PMPR)-Kanpur(BPU)	2.8	0.6	7.1	48.3	59.0
	Kanpur – Tundla	2.9	1.9	10.0	48.7	63.5
	Tundla - Aligarh	3.1	0.6	1.9	46.5	52.1
	Alighar – Khurja	3.1		1.9	44.4	49.4
	Khurja – Dadri					
2018-19	Sonnagar - Mughalsarai	4.8	1.8	9.5	66.2	82.3
	Mughalsarai - Allahabad	5.1	2.2	14.7	51.5	73.5
	Allahabad – Kanpur	5.1	0.8	7.4	67.8	81.2
	Kanpur(PMPR)-Kanpur(BPU)	6.0	0.8	8.0	70.0	85.0
	Kanpur – Tundla	6.0	2.1	11.7	73.1	93.1
	Tundla - Aligarh	6.2	1.0	4.0	71.9	83.3
	Alighar – Khurja	6.3	0.3	4.0	69.6	80.2
	Khurja – Dadri	3.2	0.8	4.0	37.5	45.5
2023-24	Sonnagar - Mughalsarai	5.4	2.0	10.6	68.7	86.7
	Mughalsarai - Allahabad	5.6	2.5	16.4	53.2	77.6
	Allahabad – Kanpur	5.7	0.9	7.6	69.1	83.4
	Kanpur(PMPR)-Kanpur(BPU)	6.7	0.9	8.2	72.3	88.2
	Kanpur – Tundla	6.7	2.3	12.3	75.6	97.1
	Tundla - Aligarh	7.0	1.1	4.7	74.5	87.3
	Alighar – Khurja	7.0	0.3	4.6	71.8	83.8
	Khurja – Dadri	3.6	0.9	4.5	38.6	47.7
2028-29	Sonnagar - Mughalsarai	5.9	2.2	11.5	70.4	90.1
	Mughalsarai - Allahabad	6.2	2.8	18.0	54.4	81.5
	Allahabad – Kanpur	6.3	1.0	7.7	70.6	85.8
	Kanpur(PMPR)-Kanpur(BPU)	7.3	1.0	8.4	74.6	91.5
	Kanpur – Tundla	7.4	2.5	12.9	78.3	101.2
	Tundla - Aligarh	7.7	1.3	5.2	77.3	91.5
	Alighar – Khurja	7.7	0.4	5.1	74.2	87.5
	Khurja – Dadri	4.0	1.0	5.0	39.9	50.1
2033-34	Sonnagar - Mughalsarai	6.1	2.3	12.0	71.3	91.8
	Mughalsarai - Allahabad	6.4	3.0	19.0	55.1	83.6
	Allahabad – Kanpur	6.5	1.0	7.9	71.5	87.0
	Kanpur(PMPR)-Kanpur(BPU)	7.7	1.0	8.7	76.0	93.3
	Kanpur – Tundla	7.8	2.6	13.2	79.9	103.5
	Tundla - Aligarh	8.1	1.4	5.4	79.0	93.9
	Alighar – Khurja	8.1	0.4	5.4	75.6	89.6
	Khurja – Dadri	4.2	1.1	5.3	40.7	51.4

Note: Projection by JICA Study Team

Table 4-17 No. of Train on the Eastern DFC (Khurja – Ludhiana)

From Khurja To Lhudiana — No. of Trains per Day

Year	Section	Coal	Iron/Steel	Others	Empty	Total
2018-19	Khurja - Kalanaur	21.1	3.4	2.4	3.3	30.2
	Kalanaur - Rajpura	17.3	1.6	3.1	4.5	26.4
	Rajpura - Sirhind	5.3	2.6	6.2	11.3	25.3
	Sirhind - Ludhiana	5.3	2.6	6.2	11.3	25.3
2023-24	Khurja - Kalanaur	21.5	3.7	2.7	3.6	31.6
	Kalanaur - Rajpura	17.8	1.8	3.4	5.0	28.0
	Rajpura - Sirhind	5.6	2.8	6.8	12.5	27.8
	Sirhind - Ludhiana	5.6	2.8	6.8	12.5	27.8
2028-29	Khurja - Kalanaur	21.9	3.9	3.0	4.0	33.1
	Kalanaur - Rajpura	18.4	1.9	3.7	5.6	29.7
	Rajpura - Sirhind	5.9	3.0	7.6	13.6	30.1
	Sirhind - Ludhiana	5.9	3.0	7.6	13.6	30.1
2033-34	Khurja - Kalanaur	22.1	4.1	3.3	4.2	33.8
	Kalanaur - Rajpura	18.7	2.1	4.0	6.0	30.7
	Rajpura - Sirhind	6.0	3.2	7.9	14.1	31.2
	Sirhind - Ludhiana	6.0	3.2	7.9	14.1	31.2

From Lhudiana To Khurja — No. of Trains per Day

Year	Section	Foodgrains	Fertilizer	Others	Empty	Total
2018-19	Khurja - Kalanaur	3.2		0.3	26.5	30.0
	Kalanaur - Rajpura	3.6		1.1	21.6	26.3
	Rajpura - Sirhind	10.8		1.4	13.2	25.4
	Sirhind - Ludhiana	10.8		1.4	13.2	25.4
2023-24	Khurja - Kalanaur	3.5		0.3	27.5	31.4
	Kalanaur - Rajpura	3.9		1.3	22.5	27.8
	Rajpura - Sirhind	12.0		1.6	14.3	27.9
	Sirhind - Ludhiana	12.0		1.6	14.3	27.9
2028-29	Khurja - Kalanaur	3.9		0.3	28.6	32.9
	Kalanaur - Rajpura	4.4		1.4	23.6	29.5
	Rajpura - Sirhind	13.1		1.7	15.4	30.2
	Sirhind - Ludhiana	13.1		1.7	15.4	30.2
2033-34	Khurja - Kalanaur	4.0		0.3	29.2	33.6
	Kalanaur - Rajpura	4.7		1.6	24.3	30.5
	Rajpura - Sirhind	13.5		1.7	16.1	31.3
	Sirhind - Ludhiana	13.5		1.7	16.1	31.3

Note: Projection by JICA Study Team

Table 4-18 No. of Trains on the Western DFC

JNPT → Delhi

From JNPT To Delhi — No. of Trains per Day

Year	Section	Container	Fertilizer	Others	Empty	Total
2013-14	JNPT - Vasai Rd.					
	Vasai Rd. - Surat					
	Surat - Vadodara					
	Vadodara - Ahmedabad	21.4	1.4	1.4	7.5	31.7
	Ahmedabad - Palanpur	22.3	1.6	3.0	8.4	35.3
	Palanpur - Marwar	25.8	6.7	11.3	8.7	52.5
	Marwar - Phulera Jn	25.7	6.6	11.5	8.8	52.6
	Phulera Jn - Rewari	24.6	4.4	6.8	8.4	44.2
	Rewari - Dadri					
2018-19	JNPT - Vasai Rd.	41.1				41.1
	Vasai Rd. - Surat	43.2	0.4	2.3	12.9	58.8
	Surat - Vadodara	43.3	1.6	3.5	15.1	63.5
	Vadodara - Ahmedabad	40.9	1.8	2.8	12.5	58.0
	Ahmedabad - Palanpur	41.5	1.9	3.2	9.9	56.5
	Palanpur - Marwar	52.3	7.7	12.1	10.0	82.1
	Marwar - Phulera Jn	52.0	7.5	12.5	10.2	82.2
	Phulera Jn - Rewari	51.6	5.4	7.9	10.0	74.9
	Rewari - Dadri	23.5	0.9	1.2	0.2	25.8
2023-24	JNPT - Vasai Rd.	56.1				56.1
	Vasai Rd. - Surat	58.3	0.5	2.5	14.1	75.4
	Surat - Vadodara	58.5	1.8	3.7	16.5	80.5
	Vadodara - Ahmedabad	55.3	2.1	2.9	13.6	73.9
	Ahmedabad - Palanpur	59.8	2.2	3.4	11.0	76.4
	Palanpur - Marwar	83.3	8.5	12.7	11.1	115.6
	Marwar - Phulera Jn	82.8	8.3	13.1	11.3	115.5
	Phulera Jn - Rewari	82.4	6.2	8.6	11.1	108.3
	Rewari - Dadri	36.0	1.0	1.4	0.2	38.6
2028-29	JNPT - Vasai Rd.	68.4				68.4
	Vasai Rd. - Surat	70.8	0.6	2.6	15.5	89.5
	Surat - Vadodara	71.0	2.1	3.9	18.0	95.0
	Vadodara - Ahmedabad	67.1	2.3	3.2	14.9	87.5
	Ahmedabad - Palanpur	75.1	2.4	3.8	12.3	93.6
	Palanpur - Marwar	116.1	9.4	13.3	12.3	151.1
	Marwar - Phulera Jn	115.4	9.2	13.9	12.5	151.0
	Phulera Jn - Rewari	115.0	7.1	9.4	12.3	143.8
	Rewari - Dadri	49.0	1.2	1.3	0.3	51.8
2033-34	JNPT - Vasai Rd.	75.0				75.0
	Vasai Rd. - Surat	77.5	0.6	2.6	16.5	97.2
	Surat - Vadodara	77.7	2.2	4.1	19.0	103.0
	Vadodara - Ahmedabad	73.5	2.5	3.2	15.8	95.0
	Ahmedabad - Palanpur	82.7	2.6	3.8	13.2	102.3
	Palanpur - Marwar	137.8	10.0	13.7	13.1	174.6
	Marwar - Phulera Jn	137.0	9.8	14.4	13.3	174.5
	Phulera Jn - Rewari	136.7	7.6	10.0	13.1	167.4
	Rewari - Dadri	57.5	1.2	1.5	0.3	60.5

Note: Projection by JICA Study Team

Delhi → JNPT

From Delhi To JNPT No. of Trains per Day

Year	Section	Container	Foodgrain	Others	Empty	Total
2013-14	JNPT - Vasai Rd.					
	Vasai Rd. - Surat					
	Surat - Vadodara					
	Vadodara - Ahmedabad	20.9	6.5	1.0	2.8	31.2
	Ahmedabad - Palanpur	21.8	7.1	1.3	4.7	34.9
	Palanpur - Marwar	25.2	7.6	1.0	18.1	51.9
	Marwar-Phulera Jn	24.9	7.8	1.0	18.2	51.9
	Phulera Jn - Rewari	23.5	7.8	0.6	11.2	43.1
	Rewari - Dadri					
2018-19	JNPT - Vasai Rd.	46.6				46.6
	Vasai Rd. - Surat	48.1	7.5	5.4	2.7	63.7
	Surat - Vadodara	48.1	7.8	7.3	5.1	68.3
	Vadodara - Ahmedabad	46.3	7.7	4.8	4.5	63.3
	Ahmedabad - Palanpur	44.3	8.4	1.6	5.1	59.4
	Palanpur - Marwar	54.3	9.0	1.1	19.8	84.2
	Marwar-Phulera Jn	53.3	9.2	1.0	20.0	83.5
	Phulera Jn - Rewari	52.1	9.2	0.8	13.4	75.5
	Rewari - Dadri	25.5		0.2	2.1	27.8
2023-24	JNPT - Vasai Rd.	63.4				63.4
	Vasai Rd. - Surat	65.0	8.4	5.7	2.9	82.0
	Surat - Vadodara	65.1	8.7	7.8	5.5	87.1
	Vadodara - Ahmedabad	62.6	8.6	5.0	5.0	81.2
	Ahmedabad - Palanpur	63.3	9.3	1.7	5.6	79.9
	Palanpur - Marwar	84.7	10.0	1.1	21.2	117.0
	Marwar-Phulera Jn	83.0	10.2	1.0	21.5	115.7
	Phulera Jn - Rewari	81.8	10.2	0.9	14.8	107.7
	Rewari - Dadri	38.6	0.1	0.2	2.3	41.2
2028-29	JNPT - Vasai Rd.	77.1				77.1
	Vasai Rd. - Surat	78.9	9.4	6.1	3.1	97.5
	Surat - Vadodara	79.0	9.7	8.3	6.0	103.0
	Vadodara - Ahmedabad	76.0	9.6	5.3	5.5	96.4
	Ahmedabad - Palanpur	79.1	10.4	2.0	6.1	97.6
	Palanpur - Marwar	116.2	11.2	1.1	22.7	151.2
	Marwar-Phulera Jn	113.9	11.5	1.0	23.1	149.5
	Phulera Jn - Rewari	112.7	11.5	0.8	16.5	141.5
	Rewari - Dadri	52.0	0.1	0.1	2.6	54.8
2033-34	JNPT - Vasai Rd.	84.5				84.5
	Vasai Rd. - Surat	86.3	10.0	6.5	3.2	106.0
	Surat - Vadodara	86.4	10.4	8.7	6.3	111.8
	Vadodara - Ahmedabad	83.2	10.3	5.4	5.8	104.7
	Ahmedabad - Palanpur	87.0	11.1	2.1	6.5	106.7
	Palanpur - Marwar	136.8	11.9	1.2	23.7	173.6
	Marwar-Phulera Jn	134.2	12.2	1.1	24.2	171.7
	Phulera Jn - Rewari	133.1	12.2	0.9	17.5	163.7
	Rewari - Dadri	60.7	0.1	0.1	2.7	63.6

Note: Projection by JICA Study Team

4.4.4 Commodity-wise tonne-km projection by distance

In order to estimate revenue of the DFC, commodity-wise tonne-km was computed for several bands of distance as shown in Table 4-19. The numbers in the table means tonne-km or TEU-km on the DFC sections and distance means the travel distance between the two junction stations on the DFC.

Table 4-19 Tonne-km and TEU-km on DFC by distance band

Eastern Corridor

Year 2013 (in Milllion)

	Distance				
Commodity /km	-300	300-700	700-1000	1000-1500	-1500
Coal	240	7,767	19,177	0	0
Ore	14	2	17	0	0
Steel	14	704	480	0	0
Foodgrains	31	291	1,034	0	0
POL	248	494	40	0	0
Fertilizer	393	289	33	0	0
Cement	502	382	4	0	0
Others	689	2,545	91	0	0
Container	2	18	14	0	0

Year 2018 (in Milllion)

	Distance				
Commodity /km	-300	300-700	700-1000	1000-1500	-1500
Coal	731	9,111	34,279	3,032	0
Ore	17	6	77	17	0
Steel	18	971	1,437	668	0
Foodgrains	694	624	2,469	376	0
POL	279	500	110	3	0
Fertilizer	543	506	142	0	0
Cement	678	677	43	0	0
Others	780	2,820	327	139	0
Container	5	36	22	8	0

Year 2023 (in Milllion)

	Distance				
Commodity /km	-300	300-700	700-1000	1000-1500	-1500
Coal	3,446	9,049	34,831	8,941	0
Ore	55	8	31	93	0
Steel	27	688	1,791	1,148	0
Foodgrains	790	726	1,800	1,795	0
POL	307	494	108	27	0
Fertilizer	785	391	360	60	0
Cement	1,089	869	17	27	0
Others	1,186	1,113	2,584	260	0
Container	5	45	27	9	0

Year 2028 (in Million)

	Distance				
Commodity	-300	300-700	700-1000	1000-1500	-1500
Coal	3,552	9,448	35,513	9,103	0
Ore	64	9	34	109	0
Steel	28	734	1,869	1,197	0
Foodgrains	866	813	1,991	1,970	0
POL	307	494	108	27	0
Fertilizer	876	442	397	68	0
Cement	1,297	1,073	19	32	0
Others	1,273	1,145	2,643	275	0
Container	6	53	29	10	0

Year 2031 (in Milllion)

	Distance				
Commodity	-300	300-700	700-1000	1000-1500	-1500
Coal	3,617	9,690	35,931	9,162	0
Ore	70	9	36	117	0
Steel	29	761	1,918	1,223	0
Foodgrains	904	860	2,076	2,033	0
POL	307	494	108	27	0
Fertilizer	930	475	417	72	0
Cement	1,410	1,188	21	35	0
Others	1,321	1,164	2,669	277	0
Container	6	58	30	10	0

Western Corridor

Year 2013 (in Million)

	Distance				
Commodity	-300	300-700	700-1000	1000-1500	-1500
Coal	0	311	4	0	0
Ore	0	0	2	0	0
Steel	0	69	125	0	0
Foodgrains	0	325	4,646	0	0
POL	1	964	707	0	0
Fertilizer	5	2,169	870	0	0
Cement	112	171	0	0	0
Others	0	2,284	585	0	0
Container	0	155	1,179	0	0

Year 2018 (in Million)

	Distance				
Commodity	-300	300-700	700-1000	1000-1500	-1500
Coal	9	163	227	7	0
Ore	5	17	0	4	0
Steel	103	118	0	206	0
Foodgrains	11	479	450	6,875	0
POL	44	1,282	334	516	0
Fertilizer	141	2,581	717	946	0
Cement	40	502	0	0	0
Others	120	2,898	693	336	0
Container	2	449	352	3,268	0

Year 2023 (in Million)

	Distance				
Commodity	-300	300-700	700-1000	1000-1500	-1500
Coal	10	184	256	17	0
Ore	5	17	0	5	0
Steel	115	73	91	239	0
Foodgrains	12	537	508	7,654	0
POL	44	1,282	334	516	0
Fertilizer	146	2,825	832	1,083	0
Cement	41	611	0	0	0
Others	120	3,050	923	373	0
Container	2	811	792	4,432	0

Year 2028 (in Million)

	Distance				
Commodity	-300	300-700	700-1000	1000-1500	-1500
Coal	11	207	288	19	0
Ore	6	17	0	6	0
Steel	123	81	91	278	0
Foodgrains	14	601	572	8,549	0
POL	44	1,282	334	516	0
Fertilizer	152	3,088	950	1,240	0
Cement	42	739	0	0	0
Others	121	3,232	1,018	414	0
Container	3	1,271	1,283	5,383	0

Year 2031 (in Million)

	Distance				
Commodity	-300	300-700	700-1000	1000-1500	-1500
Coal	11	222	308	21	0
Ore	6	17	0	6	0
Steel	128	87	91	304	0
Foodgrains	15	640	611	9,122	0
POL	44	1,282	334	516	0
Fertilizer	155	3,259	1,025	1,340	0
Cement	43	823	0	0	0
Others	122	3,348	1,076	441	0
Container	3	1,628	1,595	5,894	0

Source: JICA Study Team

CHAPTER 5
COMPARISON OF BASIC TECHNICAL OPTIONS

CHAPTER 5 COMPARISON OF BASIC TECHNICAL OPTIONS

5.1 COMPARISON OF CONTAINER TRANSPORT SYSTEMS

5.1.1 MMD for DSC transport

In principle, the railway system infrastructure should be designed and constructed so as not to interfere with the Maximum Moving Dimensions (MMD), which is defined in correspondence to the loading gauge. This measure guarantees the safety of railway operations. The principle is equally applicable to Double-Stack Container (DSC) operations. The MMD for DSCs have been shown in *Volume 2-Task 0&1, Section 8.5: Maximum Moving Dimension and Wagons Parameters (Figure 8-10)*, which was studied by RDSO. Figure 8-10 is shown again below. However, the MMD is not fixed, as mentioned in *PETS-II W.F.C., Chapter 10: Rolling Stocks "Height of MMD is 6.8 m, Width of MMD is 4.725 m. And the issue of MMD and SOD is under consideration of RDSO as per directions of Railway Board.")*

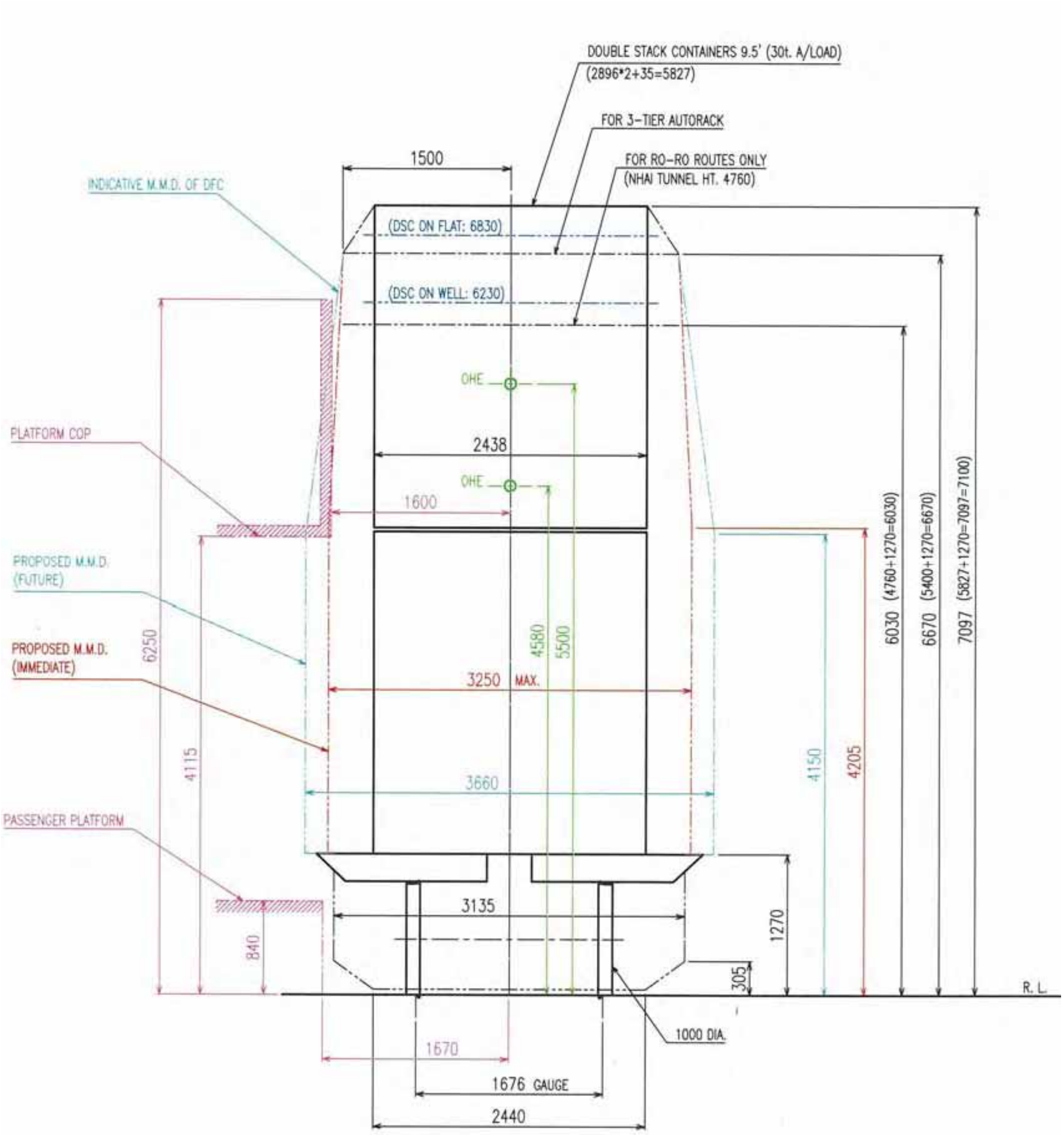


Figure 5-1 MMD as Studied by RDSO

JICA Study Team (JST) has studied the MMD related to Double stack container (DSC) traffic, which is 6.83 m for DSCs on flat-type wagons, and 6.23 m for DSCs on well-type wagons. These are also shown in Figure 5-1. DSC height is lower by 0.6 m for the well-type wagons. Either diesel or electric locomotives may be used for haulage. Haulage by electric locomotive is covered in the succeeding sections.

It appears that Chinese Railways introduced $8+8^{1/2}$ ft loading to avoid having to reconstruct its infrastructure. For the DFC project, however, new MMD are proposed so that a $9^{1/2}+9^{1/2}$ ft option may be introduced.

The RITES report only addresses the loading gauge in terms of handling loads with large cross-sections, such as the DSCs and transport wagons shown in *Figure 7-43*. However, the loading gauge, transport capacity, and construction or improvement costs are all key issues when addressing the viability of inter-operability incorporating the existing feeder lines. It should also be noted that the loading gauge to be adopted for the DFC may get modified in the final design stage.

The first study done by RDSO resulted in 7,100 mm as the top height of DSCs on flat wagons, assuming a floor height of 1,270 mm. PETS-II fixed 6800 mm as the maximum height of rolling stock by modifying the floor height to 1,005 mm and equipping the BLC wagon with 840 mm radius wheels.

In this study, JST assumes floor heights of 1000 mm for flat wagons and 400 mm for well wagons. Taking 2,896 mm as the height of a $9^{1/2}$-ft container, the maximum height of moving dimensions of a DSC wagon works out to be 6,830 mm for flat-type and 6,230 mm for well-type wagons. These are shown in Figure 5-2 and Figure 5-3.

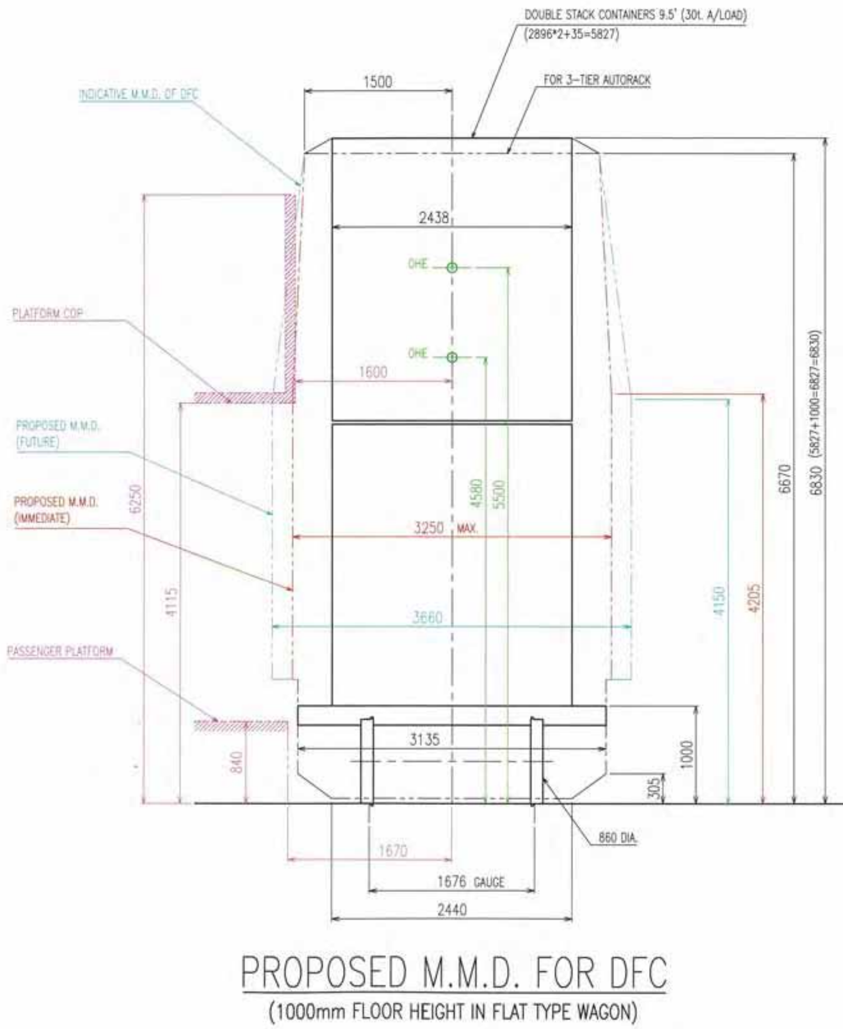


Figure 5-3 Proposed MMD for DSCs on Flat-type Wagons

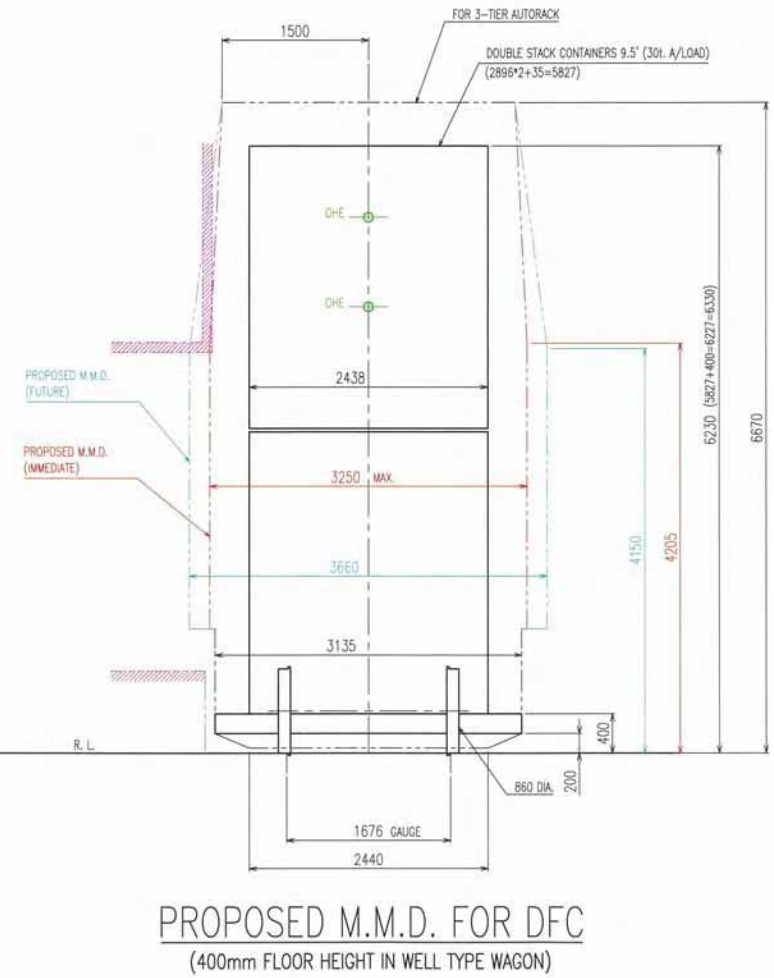


Figure 5-2 Proposed MMD for DSCs on Well-type Wagons

5.1.2 Site survey of DSC train operations in China

Chinese Railways started the operation of DSCs on April 18th, 2007, between Beijing and Shanghai and on another section after a trial operation of two years. A JST delegation visited China and surveyed the operating situation of DSCs at the end of April 2007. The commercial service policies of Chinese Railways relating to DSCs were studied during this survey and are introduced below.

(1) Most of the DSC transport will be running on the electrified sections.

Chinese Railways is planning to install electrification equipment (AC 25kV) on its main lines. The volume of container transport seems to have increased so much on these main lines that they are planning to run DSCs on all the electrified sections. A comparison of electrified sections in China and India is shown in Table 5-1. As the situation is similar in both countries, it is very likely that India will face a similar demand to run DSCs on its main lines in the future.

Table 5-1 Ratio of Electrification

Item	China	India
Ratio of electrification	29.2%	27.0%
Ratio of ton-km on the electrified sections compared with ton-km on all lines	52.8%	63.0%

Source; Electrified ratio: UIC Statistics 2002
Ton-km: India Annual Year Book 2005-06, China Chinese Railway Year Book 2006

When a DSC train runs on an existing electrified section, structures such as road over-bridges (ROB) can be a hindrance. To reduce the reconstruction of such structures on the existing line as much as possible, Chinese Railways has adopted the use of well-type wagon for DSCs, and limited the height of the loading container to 8 ft (for the lower berth) and $8^{1/2}$ ft (for the upper berth) for the time being. This will lower the height of wagons so as to keep the minimum height of the contact wire at 5.7 m. The improvement cost between Beijing and Shanghai (1,318 km) was about USD 300 million. Plans for the future will allow containers with a height of $8^{1/2}$ ft (lower berth) and $9^{1/2}$ ft (upper berth) to be loaded onto the well-type wagons. At that stage, the height of the contact wire will be increased to 6.33 m.

To minimize the cost of improvement on existing lines for the case of double-stacking $9^{1/2}$-ft containers, a loading pattern of $8^{1/2}$ ft for the lower berth and $9^{1/2}$ ft for the upper berth is adopted. In order to lower the centre of gravity of the wagon, the 20-ft container (height $8^{1/2}$ ft) is generally used for heavy-weight cargo and is loaded onto the lower berth. The 40-ft container (height $9^{1/2}$ ft) is used for freight whose ratio of weight to volume is rather small, and is loaded on the upper berth.

In China, the number of the wagons (2TEUs) of a Single-Stack Container (SSC) train is 50. The number of the well-type wagons (4TEUs) of a DSC train is 38. The use of wagons with articulated trucks, which are operated in the U.S.A., has not been adopted by Chinese Railways because of axle weight restrictions.

The voltage of the contact wire is 25 kV. For safety, container trains are moved to unwired sidings at terminals for loading and unloading and to provide for crane operations.

(2) Need to lower the centre of gravity for stable running & improvement in speed.

When the centre of gravity of the wagon rises, speed restrictions on the train become indispensable to counter the rolling movement at straight sections and centrifugal force at curved sections. During an examination of DSC operations with the flat-type wagon, which

RDSO of Indian Railways has studied and proposed, it was found that the maximum running speed has been limited to 75 km/h for DSCs. The maximum speed of DSCs using the well-type wagon is stipulated at 70 mph (112 km/h) in the United States and 120 km/h in China. Chinese Railways has extensively studied the running characteristics with respect to the height of the centre of gravity before introducing the DSC, and had ruled that for DSC operations, the height of the centre of gravity of the wagon shall be less than 2.0 m. After having carried out a trial run for two years and being convinced of its safety, Chinese Railways raised the height of the centre of gravity of the well-type wagon up to 2.2 m. This is reflected in the manner of the container loading that was mentioned above. In addition, in selecting lines for commercial operation in the future, the lines that pass through the areas with strong wind have been excluded from DSC operations.

Photo 5-1 A Well-type Wagon at Loading Area (Beijing)

Photo 5-2 The Internal Structure of the Well-type Wagon (Shanghai)

Photo: JICA Study Team

5.1.3 Cost-benefit analysis of the SSC and DSC

In the existing studies on the DFC, the flat-type wagon was recommended by RITES for DSC operations on the DFC based on the following reasons:

1) Maximizing transport capacity.
2) Reducing transport cost by half compared to SSC operations.

However, the following negative points should also be examined carefully when selecting the container stack configuration for the DFC.

a) Heights of ROBs and all other overhead structures will need to be raised in order to secure adequate vertical clearance for the DSC trains. Therefore, the construction cost of the DFC will increase in comparison to using the SSC, and it is necessary to verify the economic feasibility of the investment.

b) Some freight trains on the DFC will also run on the existing lines. Hence, reconstruction of the overhead structures on these existing lines will also be necessary to secure adequate vertical clearance for DSC trains. The cost of this work should be included as part of the initial cost of the DFC.

c) In India, the ratio of personnel expenses as part of the total railway operation cost is relatively low. Therefore, the reduction in the number of trains from adopting the DSC will result in the higher operation costs per train compared to the SSC, since the construction costs must be borne by smaller number of trains.

From the above point of view, a cost-benefit analysis on container stack options for the Western DFC was carried out for the five options below in order to identify the best mix of container stack configurations, wagon types and locomotive type (See Table 5-2).

The SSC diesel train, which requires the least initial cost, is used as the base case.

Table 5-2 Container Stack Options for Cost-benefit Analysis

No.	Container stack method	Wagon type	Locomotive type	Number of wagons	Capacity (TEUs/train)
Base Case	SSC	Flat	Diesel	45	90
Case 1.	SSC	Flat	Electric	45	90
Case 2.	DSC	Well	Diesel	32	128
Case 3.	DSC	Flat	Diesel	45	180
Case 4.	DSC	Well	Electric	32	128
Case 5.	DSC	Flat	Electric	45	180

Source; JICA Study Team

The cost items considered in this analysis are as follow:

1) Capital cost
   - Rolling stock procurement cost (locomotives and wagons)
   - Construction cost of electric facilities
   - ROB reconstruction cost
2) O&M cost
   - Maintenance cost (locomotives and wagons)
   - Electric facilities maintenance cost
   - Personnel cost such as drivers
3) Energy cost (diesel oil and electricity)

   In addition, the incremental fare income (0.67 Rs/t-km) brought about from the DSC, which can transport the cargo that cannot be transported by SSC trains because of the shortage of line capacity, is counted as a benefit of using DSCs.

   The starting year of the DFC, evaluation period, and the ratio of SSC train which run through to the existing lines are set as follow.

   - Commencement of operation: 2013 / 2014
   - Evaluation period: 26 years (including 5-year construction period)
   - Ratio of container trains connecting to the existing line: 30%

(1) Rolling stock options

The number and assumed unit price of locomotives for each option are shown in .

Table 5-3. Similarly, the number and assumed unit price of wagons for each option are shown in Table 5-4. Note that the bulk wagon was excluded from this analysis because all cases have the same condition. The performance of the locomotives were presented in the *Chapter 7 and Volume4 Technical Working Paper Task2, 7-(8).* In consideration of differences in climatic conditions, the maximum power of the locomotives was estimated to have a 30 % de-rating in comparison to the latest European and Japanese high power locomotives.

Table 5-3 Condition of Locomotives

	Container			Bulk
	SSC	DSC		
		Well-type	Flat-type	
Electric loco				
Number of locomotives and power of each	1 locomotive with 6-axles (6,000HP)	1 locomotive with 6-axles (7,200HP)	1 locomotive with 6-axles (9,000HP)	1 locomotive with 8-axles (12,000HP)
Unit price	Rs.10.6Crore	Rs.13.0 Crore	Rs.14.5 Crore	Rs.21.2 Crore
Diesel loco				
Number of locomotives and power of each	1 locomotive with 6-axles (4,000HP)	1 locomotives with 6-axles (5,000HP)	1 locomotive with 6-axles (5,000HP)	2 locomotives with 6-axles (5,000HP×2)
Unit price	Rs.10.6 Crore	Rs.13.0 Crore	Rs.13.0 Crore	Rs.26.0 Crore

Source: JICA Study Team

Table 5-4 Number and the Assumption Price of Wagons per Train

	SSC	DSC	
		Well-type	Flat-type
Number of wagons per one train	45	32	45
Unit	Rs.0.18 Crore	Rs.0.26 Crore	Rs.0.20 Crore

Source: JICA Study Team

(2) Traffic demand and procurement of rolling stock

The following assumptions were applied in estimating the future traffic demand and required number of train units.

1) Two types of operation were analyzed for the container trains which run only within the DFC section, namely:

   a) DSC option shall be applied to all the trains (Option 1)

   b) SSC option shall be applied to as many trains as possible; and DSC option shall be applied only if the number of trains exceeds the line capacity (140 trains/day/direction). (Option 2)

   It is assumed that if the traffic demand exceeds the line capacity even through DSC option are applied to all trains, the surplus demand will be transported by trucks.

2) Bulk cargo trains and container trains which run through to the feeder line have the priority in securing the required number of trains.

The growth rate of traffic demand and the required number of train units are calculated from the demand forecast and transportation plan examined in this study. In this calculation, the maximum speed of flat-type DSCs and other types of trains are set at 75 km/h and 100 km/h, respectively. The average speeds of all types of trains are assumed at 70% of the maximum speed. The traffic demand and required number of train units in 2013/14, 2018/19, 2023/24, 2028/29 and 2033/34 are shown in Table 5-5(1)-(3).

When the number of the trains exceeds track capacity, the following hierarchy is applied in calculating the number of each type of train:

- 1st priority: Bulk freight train
- 2nd priority: SSC train runs through on the existing line
- 3rd priority: DSC train

Table 5-5 (1) Future Traffic Demand on the Western Corridor, and Required Number of Train Units for Bulk Trains and SSC Trains Running Through Feeder Lines

Year	Traffic demand on Western Corridor				SSC running through to the feeder line Bulk Cargo	
	Bulk Cargo		Container			
	Traffic Volume (Mil. Ton-km)	Number of train per direction	Traffic volume (Mil. TEU-km)	Number of trains per direction	Traffic volume (Mil.TEU-km)	Number of train Units
2013/14	13,351	23	1,335	26	401	8
2018/19	20,029	32	4,074	60	1,222	18
2023/24	21,903	35	6,037	93	1,811	28
2028/29	24,036	38	7,940	127	2,382	38
2033/34	25,397	40	9,120	149	2,736	45

Source: JICA Study Team

Table 5-5 (2) Traffic Volume and Number of Train Units on DFC (Option 1)

Year			Bulk traffic demand (Excluding feeder connecting train)	Base case Case 1	Well-type Case 2 and Case 4		Flat-type Case 3 and Case 5	
				SSC	SSC	DSC	SSC	DSC
2013/14	Traffic volume		13,351 Mil. T-km	1,335 Mil. TEU-km				
	Nos.of loco	Electric	37	49	15	23	15	21
		Diesel	74	49	15	23	15	21
2018/19	Traffic volume		20,029 Mil. T-km	4,074 Mil. TEU-km				
	Nos.of loco	Electric	55	134	41	63	41	58
		Diesel	110	134	41	63	41	58
2023/24	Traffic volume		21,903 Mil. T-km	6,037 Mil. TEU-km				
	Nos.of loco	Electric	59	202	61	94	61	87
		Diesel	118	202	61	94	61	87
2028/29	Traffic volume		24,036 Mil. T-km	7,940 Mil. TEU-km				
	Nos.of loco	Electric	64	268	84	129	84	119
		Diesel	128	268	84	129	84	119
2033/34	Traffic volume		25,397 Mil. T-km	9,120 Mil. TEU-km				
	Nos.of loco	Electric	68	268	94	145	94	133
		Diesel	136	268	94	145	94	133

Source: JICA Study Team

Table 5-5 (3) Transport Volume and Number of Train Units on DFC (Option 2)

Year			Bulk traffic demand (Excluding feeder connecting train)	Base case Case 1	Well-type Case 2 and Case 4		Flat-type Case 3 and Case 5	
				SSC	SSC	DSC	SSC	DSC
2013/14	Traffic volume		13,351 Mil. T-km	1,335 Mil. TEU-km				
	Nos.of loco	Electric	37	49	49	0	49	0
		Diesel	74	49	49	0	49	0
2018/19	Traffic volume		20,029 Mil. T-km	4,074 Mil. TEU-km				
	Nos.of loco	Electric	55	134	134	0	134	0
		Diesel	110	134	134	0	134	0
2023/24	Traffic volume		21,903 Mil. T-km	6,037 Mil. TEU-km				
	Nos.of loco	Electric	59	202	202	0	202	0
		Diesel	118	202	202	0	202	0
2028/29	Traffic volume		24,036 Mil. T-km	7,940 Mil. TEU-km				
	Nos.of loco	Electric	64	268	192	51	218	32
		Diesel	128	268	192	51	218	32
2033/34	Traffic volume		25,397 Mil. T-km	9,120 Mil. TEU-km				
	Nos.of loco	Electric	68	268	94	154	94	133
		Diesel	136	268	94	154	94	133

Source: JICA Study Team

(3) Construction costs of electric facilities

The cost of electric traction facilities for the JNPT-Ahmedabad section (569 km) and the Ahmedabad-Dadri section (899 km), a total of 1,468 km, was shown to be Rs. 0.50 cr. per kilometre, according to the costs in *RITES Report on the Eastern Corridor*. However, the plan at the first stage was to use the existing substations along the DFC route to supply electric power to the DFC lines. The costs for new substations and transmission lines were thus not included. However, in order to provide a full cost estimation, the estimated costs related to these facilities are shown in Table 5-6. This assumes the introduction of a 2x25 kV AT system and the positioning of a substation every 50 km along JNPT-Ahmedabad-Dadri section.

Maintenance costs of these electric facilities are estimated to be 2% of the construction cost annually, with major maintenance costing 10% every 10 years.

Table 5-6 Cost of Electric Facilities Related to the Western Corridor

(Unit: *Crore Rs.)

	Unit cost	Quantity	Total cost
Electrification cost	0.55	2,936 T km	1,610.31

Source; JICA Study Team

(4) Reconstruction cost of ROBs

529 ROBs would need to be reconstructed to obtain the required height clearances. The costs of reconstruction are estimated for each option as tabulated below. Note that the costs shown include all the reconstruction work that would be conducted by MOR in the future.

Table 5-7 Height Clearance and Reconstruction Cost of ROBs (529 bridges)

	SSC/DSC	Wagon type	Traction	Height (m)	Reconstruction cost (Crore Rs.)
Base Case	SSC	Flat	Diesel	10.10	3,411.7
Case 1	SSC	Flat	Electric	10.46	3,574.1
Case 2	DSC	Well	Diesel	11.39	4,026.6
Case 3	DSC	Flat	Diesel	11.99	4,287.9
Case 4	DSC	Well	Electric	11.75	4,194.9
Case 5	DSC	Flat	Electric	12.35	4,485.5

Source: JICA Study Team

(5) Operation and maintenance cost

Maintenance costs for locomotives were obtained from Table 30 of the *Annual Statistic Statements 2004-05* and are shown in Table 5-8. Note that the maintenance cost of electric locomotives is shown as Rs. 7.18 per 1,000 GT km (gross tonne kilometres), or about 55% of that of diesel locomotives.

Maintenance costs of electric facilities are estimated to be 2% of the construction cost annually.

The personnel costs, such as drivers, are estimated based on the MOR statistics as shown below.

Table 5-8 Operation and Maintenance Cost

	Traction	Cost
Locomotive maintenance cost	Electric	7.18 Rs./1000 GT-km
-ditto-	Diesel	12.94 Rs./1000 GT-km
Electric facility maintenance cost	Electric	36.8 Crore Rs./year
Personnel cost	Common	716 Rs./100 Train-km

Source; Annual Statistic Statements 2004-05

(6) Energy cost

Energy consumption and the costs on Zonal Railways related to the Western Corridor were calculated and are shown in Table 5-9 based on data obtained from *Tables 27(A), 27(B) and 38* in *the Annual Statistic Statements 2004-05.* Note that the energy cost of electric traction becomes 53% that of diesel traction when viewed in terms of distance-weighted average energy cost.

Table 5-9 Energy Consumption and Energy Cost

		Consumption per 1,000 GT. km Litre or kWh*	Unit price Rs./litre or kWh**	Energy Cost Rs./ 1000GT. km
Diesel loco	Central	3.03	28.42	86.11
	Western	2.57	28.67	73.68
	North Western	2.12	25.12	53.52
	Northern	2.10	22.33	46.89
	Distance weighted average of each ZR***			62.80
Electric loco	Central	8.52	4.04	34.42
	Western	7.49	4.73	35.43
	North Western	NA	NA	NA
	Northern	5.70	4.20	23.94
	Distance weighted average of each ZR			33.44

* Column 18 in Table 27(B), GT. kms: Gross Tonne kilometres
** Column 68 and 74 of Table 27(A)
***CR: 70 km JNPT/Vasai Rd., WR: 600km Vasai Rd./Palanpur, NWR: 633 km Palanpur/Rewari, NR: 133 km Rewari/Dadri
Source; Annual Statistic Statements 2004-05

(7) Cost-benefit analysis

The cost-benefit analysis was conducted by adopting the conditions discussed above, and the results are shown in Table 5-10. Case 4 (DSC train, well-type wagon, electric engine) shows the best value for all the indexes. Ranking by IRR (Internal Rate of Return) is shown below. The detailed calculation results are shown in *Volume 4 Technical Working Papers Task2, 5-(3): Cost Benefit Analysis on Container Options.*

Case 1 > Case4 > Case5 > Case2 > Case3

Table 5-10 Result of Cost-benefit Analysis (Summary)

		SSC/DSC	Wagon type	Traction	IRR	NPV (D/R=12%)	B/C (D/R=12%)
-	Case 1	SSC	Flat	Electric	22.61%	857.2 Crore Rs.	1.73
Option 1	Case 2	DSC	Well	Diesel	18.38%	192.8 Crore Rs.	1.57
	Case 3	DSC	Flat	Diesel	17.75%	209.2 Crore Rs.	1.50
	Case 4	DSC	Well	Electric	19.47%	882.3 Crore Rs.	2.54
	Case 5	DSC	Flat	Electric	18.46%	819.0 Crore Rs.	1.46
Option 2	Case 2	DSC	Well	Diesel	3.14%	-266.6 Crore Rs.	0.39
	Case 3	DSC	Flat	Diesel	1.93%	-361.2 Crore Rs.	0.23
	Case 4	DSC	Well	Electric	16.80%	574.3 Crore Rs.	1.38
	Case 5	DSC	Flat	Electric	15.57%	453.73 Crore Rs.	1.25

Source: JICA Study Team

Option 1: DSC used for all the trains.

Option 2: SSC used for as many trains as possible. DSC to be used only if the number of trains exceeds the line capacity (140 trains/day/direction).

(8) Unit transportation cost

The unit transportation cost for SSCs, DSCs on flat-type wagons, and DSCs on well-type wagons in the electrified section are shown in Table 5-11. The year 2023/24 was used as the horizon year.

In terms of depreciation costs, the DSC on flat-type wagon is the most expensive option, followed by the DSC on well-type wagon and the SSC. This results from the higher unit price of locomotives for DSC train hauling, and more expensive depreciation cost of ROBs and electric facilities per train compared to the SSC.

In terms of O&M cost, SSC is the most expensive option, followed by the DSC on well-type wagon and that on the flat-wagon.

For the total TEU-km cost, the DSC on well-type wagon becomes the most economical option, closely followed by the DSC on flat-type wagon and the SSC. This index shows that the DSC reduces the unit transport cost per TEU by about 20%.

The detailed calculation results are shown in Volume 4 Technical Working Papers Task 2, 5-(4): Unit Cost by Wagon Type.

Table 5-11 Transportation Cost per TEU km

Unit; Rs per TEU km

Items			SSC	DSC-well	DSC-flat
Depreciation cost	Electric Locomotive		0.098	0.090	0.083
	Wagon		0.185	0.134	0.103
	ROB		0.096	0.046	0.064
	Electric facility		0.048	0.048	0.048
	Subtotal		0.427	0.318	0.298
O&M cost	Energy cost		0.767	0.595	0.584
	Maintenance cost	Electric locomotive	0.165	0.128	0.126
		Wagon	0.146	0.073	0.073
		Electric facility	0.061	0.061	0.061
	Personnel cost		0.513	0.407	0.402
	Subtotal		1.652	1.261	1.246
Total			2.079 (100)	1.579 (75.9)	1.544 (74.3)

Source: JICA Study Team

5.1.4 Recommendations for the operation of the DSC train

According to the cost analysis that is shown in the previous section, Case 4 (DSC train, well-type wagon, electric traction) is at present the most practical and economical choice for DSC train operations on the Western DFC.

Recommendations for the operation of the DSC train are shown below.

(1) Proven technology of DSC operations

In the USA, Australia, China and other countries, DSC trains have been operated safely (see Table 5-12). In China, DSC trains are hauled by electric engines. In the US East Coast, DSC trains are operated by diesel engines under contact wires on AC-electrified sections. In both cases, well-type wagons are used. By maintaining a clearance of more than 270 mm between the contact wire and containers, no safety incidents such as electrical short circuiting have occurred. On the other hand, the DSC on flat-type wagons has not been adopted anywhere in the world except for some short duration trials in India. Therefore, it is difficult at present to claim that the DSC on flat-type wagons is a proven technology. If IR intends to introduce the DSC on flat-type wagons for commercial operations, meticulous prior testing for sufficiently long periods will be necessary to confirm safety for different loading patterns under various running conditions of track and climate

Table 5-12 Traction Systems of DSC

Transport System	Diesel Traction	Electric Traction	Note
DSC on well-type wagons	Proven in US, Australia. Maximum speeds are 112 km/h	Proven in China. Maximum speed is 120 km/h	Started from the late 80s. There are many examples and stabilised transport technologies including wagon design.
DSC on flat-type wagons	Not proven, only tested in India. Maximum speed is 75 km/h	Not proven	Not yet commercialised anywhere in the world. Requires meticulous examination for running stability, under various loading and wind conditions.

Source: JICA Study Team

(2) Safety

1) Height of centre of gravity and speed restrictions at curves

Heights of gravity centre are calculated as shown in Table 5-13(1), Table 5-13(2), Table 5-13(3) and Table 5-13(4). DSCs on well-type wagons have a lower centre of gravity than DSCs on flat-type wagons, meaning that the well-type option can increase the passing speed at curves. When 20-ft containers are loaded on the lower berth, the gravity centre becomes lower than that of the combination of 40-ft containers. Detailed studies are shown in *Volume 4 Technical Working Paper Task2, 5-(2): Height of Centre of gravity and Speed Restrictions at Curves.*

It is difficult at the present to define a maximum height of gravity centre for operation without any test data. However, a lower height is unquestionably better; therefore, it is recommended that well-type wagons be adopted, and loading conditions be controlled to avoid Case-2 situations (upper berth loaded and lower berth empty).

Table 5-13 (1) Heights of Gravity Centre for $9^{1/2}$ft + $9^{1/2}$ft on Flat-type Wagons

	Case-1	Case-2	Case-3	Case-4
Upper container	Empty 40 ft	Loaded 40 ft	Empty 40 ft	Loaded 40 ft
Lower container	Empty 40 ft	Empty 40 ft	Loaded 40 ft	Loaded 40 ft
Height of GC mm	2,856	4,007	1,558	2,755
Speed limit at 700R km/h	86	73	117	88

Source: JICA Study Team

Table 5-13 (2) Heights of Gravity Centre for $9^{1/2}$ft + $9^{1/2}$ft on Well-type Wagons

	Case-1	Case-2	Case-3	Case-4
Upper container	Empty 40 ft	Loaded 40 ft	Empty 40 ft	Loaded 40 ft
Lower container	Empty 40 ft	Empty 40 ft	Loaded 40 ft	Loaded 40 ft
Height of GC mm	2,314	3,419	1,281	2,364
Speed limit at 700R km/h	96	79	129	95

Source: JICA Study Team

Table 5-13 (3) Heights of Gravity Centre for $9^{1/2}$ft + $8^{1/2}$ft on Flat-type wagons

	Case-1	Case-2	Case-3	Case-4
Upper container	Empty 40 ft	Loaded 40 ft	Empty 40 ft	Loaded 40 ft
Lower container	Empty 20 ft x2	Empty 20 ft x2	Loaded 20 ft x2	Loaded 20 ft x2
Height of GC mm	1,802	3,228	2,082	2,832
Speed limit at 700R km/h	109	81	101	87

Source: JICA Study Team

Table 5-13 (4) Heights of Gravity Centre for $9^{1/2}$ft + $8^{1/2}$ft on Well-type Wagons

	Case-1	Case-2	Case-3	Case-4
Upper container	Empty 40 ft	Loaded 40 ft	Empty 40 ft	Loaded 40 ft
Lower container	Empty 20 ft x2	Empty 20 ft x2	Loaded 20 ft x2	Loaded 20 ft x2
Height of GC mm	1,451	2,745	1,588	2,304
Speed limit at 700R km/h	121	88	116	96

Source: JICA Study Team

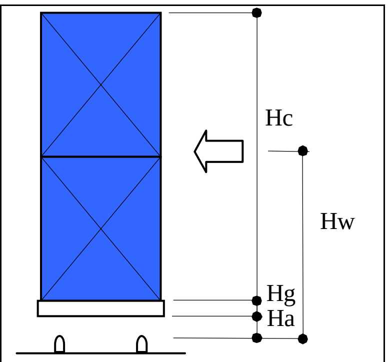
2) Preliminary Analysis on Stability of DSC against Wind Load Condition

Heights of each wagon type, flat-type and well-type wagons, are different. In other words, location of centre of gravity points and impact by wind loading for each wagon type are also different. Hence, preliminary analysis on stability of DSC for each wagon type has been carried out as follows.

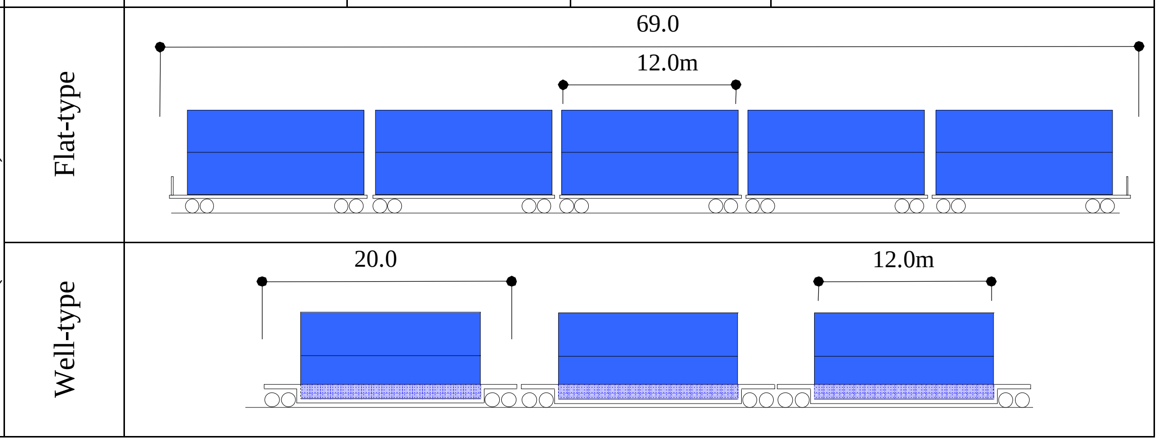
a) Schematic diagram of wind loading condition for each DSC Type

Two cases of container combination, one is 91/2 feet + 81/2 feet container combination (Case 1) and another one is 91/2 feet + 91/2 feet container combination, are considered for examining the stability of DSC by wind loads. The dimensions for each case are shown in the following table.

	Wagon type	Container combination	Case 1 $9^{1/2} + 8^{1/2}$	Case 2 $9^{1/2} + 9^{1/2}$
Height (Front view)	Flat-type	Hc :	5.49m	5.79m
		Hg :	0.20m	0.20m
		Ha :	0.80m	0.80m
		Hw :	3.645m	3.795m
	Well-type	Hc :	5.49m	5.79m
		Hg :	0.20m	0.20m
		Ha :	0.20m	0.20m
		Hw :	3.045m	3.195m



Length (Side view)



Source: JICA Study Team

Figure 5-4 Schematic Diagram of Wind Load Condition for Each DSC Type

b) Result of preliminary analysis

The base case is the well type DSC with 91/2 feet + 81/2 feet containers. This combination is accepted worldwide and is the proven system on standard gauge. Stabilities of other DSC systems are examined by comparing the calculations of variation of overturning moments and resistance moments.

The results are shown in the following table;

Table 5-14 Stability Ratio's for Each Wagon Type and Gauge

Case		A	B	C	D	Remarks
Wagon type		Well type		Flat type		
Container Combination		$9^{1/2} + 8^{1/2}$	$9^{1/2} + 9^{1/2}$	$9^{1/2} + 8^{1/2}$	$9^{1/2} + 9^{1/2}$	
Stability ratio	Standard gauge	1.00	1.10	1.73 (1.73)	1.90 (1.73)	1. The proportion of flat type wagon and well type wagon are in parentheses. （C/ A, D/ B） 2. A smaller ratio means more stability 3. Refer to *Volume 4 Technical Working Paper Task 2, 5-(1).*
	Broad gauge	0.85	0.94	1.48 (1.74)	1.63 (1.73)	

Source: JICA Study Team

c) Conclusion

The above table shows that the flat type wagon has a stability ratio that is 1.73 times larger than the well type wagon, regardless of gauge. This result concludes that flat type wagon is 1.73 times unstable in comparison with well type wagon. Wind loads have a more significant impact on the flat-type wagons than well-type wagons due to the difference of the centre of gravity point heights.

On the other hand, the stability ratio's of both wagon types on broad-gauge are lower than on standard-gauge, since the resisting force of broad gauge is higher than standard gauge due to the difference of gauge width.

A side wind speed due to overturn is more than 30m/s in running at curve of 2.5 degree (700 m radius), cant of 60 mm. Detailed studies are shown in *Volume 4 Technical Working Paper Task2, 5-(2)*. It means that side wind is not so critical factor for the DSC operation when control of train operations will be taken in gale seasons.

It is to be noted that there is no past experience and no record of stability analysis for these DSC systems on broad gauge in the world. There are many factors such as container loading, track, bogie, running speed and wind which are related to the stability and safety. Hence, further research, studies and trials including wind tunnel tests should be carried out in the future if the flat type wagons are selected for the DSC configuration. (See *Volume 4 Technical Working Paper Task2, 5-(7) Preliminary Analysis on Stability of Double-Stack Container System against Wind Loading Condition*)

Hence as per the above preliminary analysis, well type wagon for DSC system is suggested.

(3) Necessity of DSC from the viewpoint of transportation demand

According to the demand forecast for the DFC, current transport needs are met using only SSC trains for some time to come. However, it will be difficult for just SSC trains to meet the transport demands of the future. Therefore, standard facilities assuming the electrification should be set forth to enable the operation of DSCs. According to the long-term demand forecast, it seems that the total eventual demand can be met with the DSC on well-type wagons.

(4) Consideration for through operation onto the existing lines

When making a decision on the specifications of the DSC, consideration for minimizing the construction costs of the DFC and the related improvement costs of the existing lines is important. Even if it is decided that flat-type wagons running on electricity are used, a pantograph of the high lift that can support both 7.53 m (height of DFC contact wire) and 4.80 m (minimum height of existing line overhead wire) is available. There are thus no problems on the issues regarding the pantograph and overhead equipment (OHE). In the case of DSC on flat-type wagons, through operation between the existing lines and the DFC can be made possible by replacing the pantograph on the existing locomotives. For the DSC on well-type wagons, the existing pantographs may be used for the through operation. The detailed studies on pantographs to allow wider working ranges and on the structure of OHE are shown in *Section 5.2* and *Volume4 Technical Working Paper Task2, 5-(1) Contact Wire and Minimum Height of Undersurface.*

(5) Consideration from the viewpoint of transport service

The DSC trains shall be operated only to make up for the lack of the transport capacity. Normal operation shall be carried out with SSC trains. The reasons are mentioned below.

It is known that freight damage occurs more frequently in the upper berth container of DSC trains than in the lower berth because the large rolling movement of the freight.

When a SSC train to a destination with small transportation demands is converted to a DSC train, the frequency of the train operation will decrease. Therefore the stabling period of the container in port or departure ICD becomes longer, and the service level for the customer deteriorates.

Likewise, when a container is loaded or unloaded onto a DSC train, it takes more time to handle the containers because additional lifting work is required for the containers on the upper berth. Therefore, loading or unloading time per container on the DSC is 1.8 times more than that of the SSC.

The unit transport cost per container on the SSC is not much different than that of the DSC. The cost per DSC train increases with the enhancement of the capacity, and is higher than that of SSC trains. The staff cost of the drivers will decrease, but the other costs remains the same as before. Therefore, the cost per container in DSC operations does not decrease substantially compared to that for SSC trains.

(6) Unification of the specifications of the Eastern Corridor and Western Corridor

PETS-II proposes different design standards for the Western and Eastern Corridors as the DSC transports. It recommends DSC on flat-type wagons for the Western Corridor, and DSC on well-type wagons for the Eastern Corridor. Such a non-uniformity in the MMD for the two corridors will become a hindrance on through movement of DSCs between the two corridors in future. It is desirable to introduce the same design standards on both corridors.

Note, however, that according to the demand forecast for the Eastern Corridor, capacity demand for the Eastern Corridor can be met with SSCs till 2031/32.

5.1.5 Conclusions

Assuming that the maximum number of trains on the DFC is 140 per day on each direction, the line capacity will be saturated in 2023/2024 in a case of SSC train operations. DSC trains will therefore be needed after 2023/2024 at the latest. Both DSC options (flat-type and well-type wagons) are able to fulfil the transport demand further than 2031/2032, based on present demand forecasts.

The DSC on well-type wagon option has long been used in the USA, China and Australia, and has had long track records in safety. In the case of Chinese Railways, it tested the option under OHE for two years before commercial operations to confirm safety. This option is proven for both electrified and non-electrified routes.

In the case of electrified routes, a minimum clearance of 300 mm between rolling stock and OHE is required. DSC operations require designing and constructing OHE with longer masts for the required MMD. As for feasibility, JST has checked and concluded that an appropriate design can be devised to construct higher OHE masts corresponding to higher rolling stock MMD. The appropriate design method of OHE for the DSC on flat-type wagons has been examined for the DFC where the height of the contact wire is 7.53 m as shown in *Volume 4 Technical Working Paper Task2, 5-(4) Section2.* Chinese Railways also keeps more than 300 mm clearances for every train operation under 25 kV OHE.

The DSC on flat-type wagons has been tested only in India for a short period, and other railway systems have not introduced the option, whether routes are electrified or not. The higher centre of gravity of DSCs on flat-type wagons is a matter of great concern on the issue for safety. It may be applicable to introduce the DSC on flat option only at the stage that safety operation was confirmed after exhaustive and meticulous test running for different loading conditions over a sufficiently long period. Chinese Railways had tested its DSC train operation sufficiently before commercial implementation.

The maximum speed of the DSC on flat-type wagons is limited to 75 km/h, according to the study done by RDSO. DSCs on well-type wagons are operated at more than 100 km/h in the USA and China.

As for pantographs that are needed to enable through operation between the DFC (with large MMD) and the existing lines (with relatively smaller MMD), the existing pantographs can be adapted for the DSC on well-type wagons. The DSC on flat-type wagons will require acquiring a new type of pantograph to obtain wider working ranges. The wide working-range pantograph is already developed and available. As such, there are no obstacles to through operation related to the pantograph.

The unit transportation cost for the DSC on flat-type wagons and on well-type wagons are nearly the same, at 74.3 % and 75.9% respectively, of the SSC, according to economic analysis. Therefore, there appears to be no reason to adopt the DSC on flat-type option instead of the DSC on well-type option.

As mentioned above, JST recommends the introduction of the DSC on well-type wagons for the DFC.

5.2 OHE AND PANTOGRAPH

The electrical clearances for 25 kV AC have been revised by the Ministry of Railways, but this revision is yet to be published in the Schedule of Dimensions. JST has taken these revised clearances in consideration in their studies below. The new clearances adopted are:

Minimum long time clearance: 250 mm

Minimum short time clearance: 200 mm

5.2.1 Height of rolling stock and OHE

Heights of rolling stock are calculated for two cases, 6728 mm (DSC on flat-type wagons) and 6227 mm (DSC on well-type type wagons).

OHE contact wire heights are calculated by adding distance for insulation, oscillation, erection tolerance and pre-sag. However, the contact wire can be lowered to a minimum clearance of 300 mm above the container under ROBs, as shown by Note *5 in the table below.

Total clearances for the DSC under electrification are calculated as shown in Table 5-15. They are not much different from the clearances contained in report of RITES.

For the DSC on flat-type wagons, RITES adopted 300 mm on the rolling stock height. For the DSC on well-type wagons, the relation between rolling stock height and OHE had not been defined.

Table 5-15 Heights of rolling stock and infrastructures clearances

		JST		PETS-II	
		DSC on flat-type wagon	DSC on well-type wagon	DSC on flat-type wagon	DSC on well-type wagon
Wagon	Floor height	1,000	400	1,035	400
	Containers *1	5,827	5,827	5,827	5,827
	Subtotal (A)	6,827	6,227	6,862 (6,800) *3	6,227 (6,600) *3
	MMD	6,830	6,230		
OHE	Distance for insulation	200	200		340
	Oscillation	100	100		
	Tolerance	20	20		
	Pre-sag	100	100		80
	Provision for track raising	275	275		275
	Subtotal (B)	695	695		695
OHE height (A)+(B) *2		(7.527) 7.53	(6.925) 6.93	7,100	6.922
OHE Height under Over-bridges *5		7.13	6.53		
ROB (A)+1,070 *4		7,760	7,160	7,760	7,560

*1 The height of containers is calculated by adding 35 mm, thickness of fixing on two $9^{1/2}$ ft (2,896 mm height) containers.
*2 Height of OHE is rounded up.
*3 Client's fixed size in PETS II.
*4 Minimum clearances assuming 30 m width of ROB, (OHE span of 36 m) sum of minimum insulating clearance 200 mm, oscillation 56 mm, maintenance allowance 20 mm, sag of contact wire 20 mm, thickness of contact wire 10 mm, dropper 150 mm, rise of catenary in 15 m to the edge of over the line structure 160 mm, push up by pantograph 100 mm, thickness of catenary wire 10 mm, minimum clearance 200 mm to underside of structure. The result is shown below Figure 5-5. (Note: Provision for track raising not made in this case.)
*5 Without provision for track raising

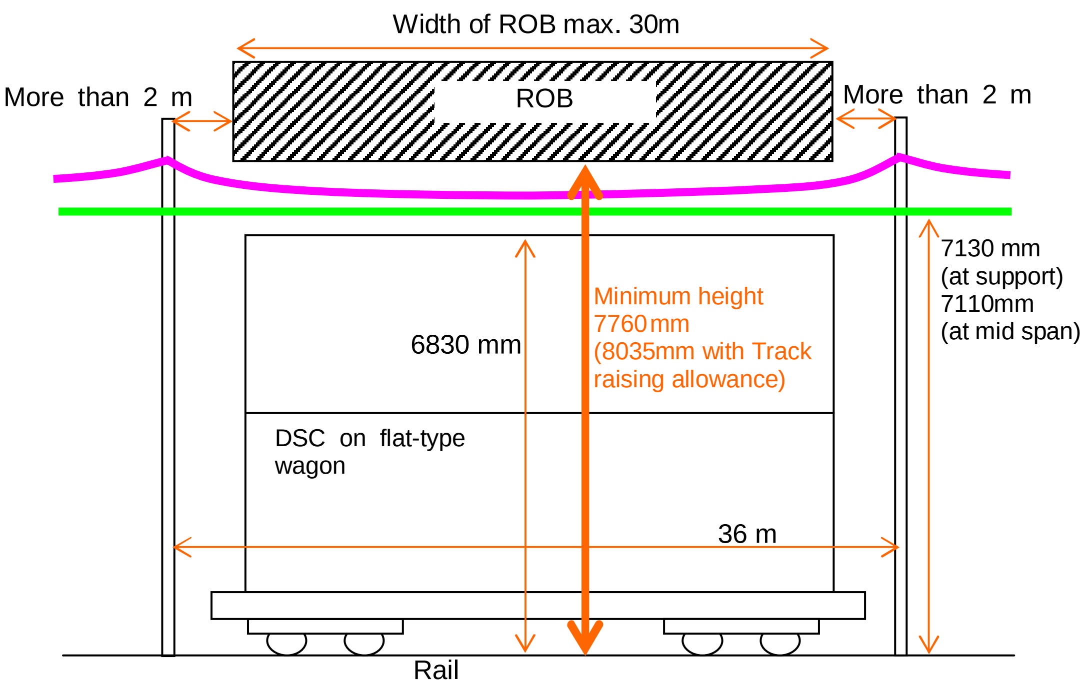


Figure 5-5 Minimum height of undersurface of ROB

5.2.2 OHE and pantograph

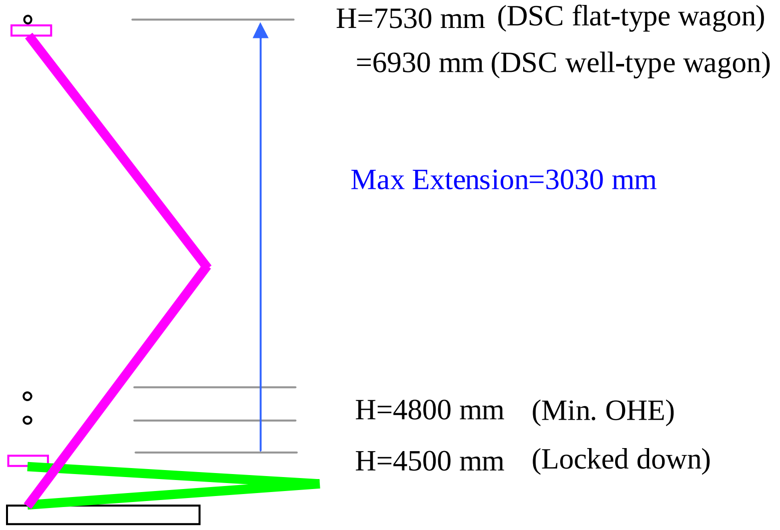
(1) DSC on flat-type wagons

As mentioned in the previous section, the OHE height is 7,130 mm minimum without provision for track raising (275 mm), and 7,530 mm normal in the case of DSC on flat-type wagons.

Minimum height of the contact wire for the existing line is 4800 mm.

The existing WAG-7 locomotives, with the current pantographs (AM-12, with locked-down height of 4,150 mm) will not work in the DFC, since the maximum working range at present is just between 4,150 to 6,645 mm. This height is way below the proposed OHE height of 7,530 mm, even if the locked-down height is raised up to 4,500 mm[1], keeping a clearance 300 mm.

It will therefore be necessary to install new pantographs that can allow for a wider working range of 3,100 mm, as shown in Figure 5-6. Its extension should be 100 mm longer than the working range. These new pantographs will make possible through operation between the DFC and the existing lines.



Note: All dimensions to R.L.

Figure 5-6 Relation between pantograph and OHE

(2) DSC on well-type wagons

In the case of DSC on well-type wagons, the OHE maximum height is 6930mm.

As mentioned above, the current pantograph (AM-12) has a working range of 2495 mm. If the locking down height is raised to 4500 mm, the AM-12 can reach a height of 6990 mm.

Therefore, the existing pantographs can be used for through operation between the DFC and the existing lines if the DSC on well-type wagon is adopted. For the flat-type option, the wide working-range pantograph proposed in the previous section will be necessary.

Example of wide working range pantographs.

[1] *PETS-II Eastern Corridor, 11.1.2* mentioned 4660 mm as new locking-down height. However the clearance to 4800 mm of the lowest live OHE of only 140 mm is insufficient.

A conceptual design corresponding to wider working range is shown in Figure 5-7.

RITES and JST independently studied examples of such pantographs. Here is an example of a European pantograph (see Figure 5-8). The example has a maximum working range of 3100 mm, and an extension of 3200 mm. Its performance allows 25 kV and 2000-ampere current collection, which fulfils the design conditions required for the DFC lines.

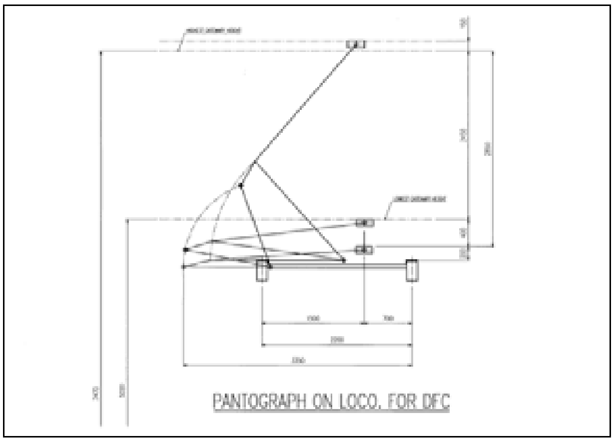
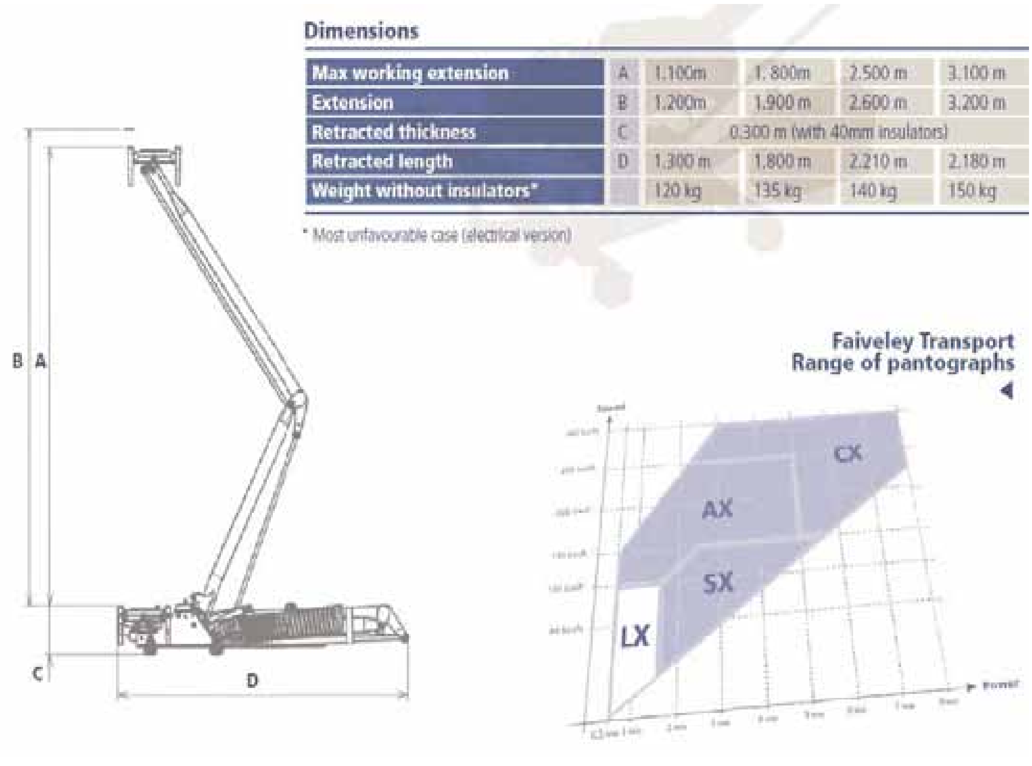


Figure 5-7 Conceptual design corresponding to wider working range



Dimensions

Max working extension	A	1.100m	1.800m	2.500 m	3.100 m
Extension	B	1.200m	1.900 m	2.600 m	3.200 m
Retracted thickness	C	0.300 m (with 40mm insulators)			
Retracted length	D	1.300 m	1.800 m	2.210 m	2.180 m
Weight without insulators*		120 kg	135 kg	140 kg	150 kg

* Most unfavourable case (electrical version)

Figure 5-8 Example of wide working-range pantograph

(3) Relation between OHE and pantograph at curves

Relationship between OHE and pantograph were examined corresponding to the raising of OHE height from 5.60 m to 7.53 m. As the result of studies focusing on relative displacement of OHE and the pantograph, it is recommended that lateral allowances be reduced by 10% from the existing design criteria. The detailed studies are shown in *Volume 4 Technical Working Paper Task2, 5-(4).*

5.2.3 Transition of OHE between the DFC and the existing line

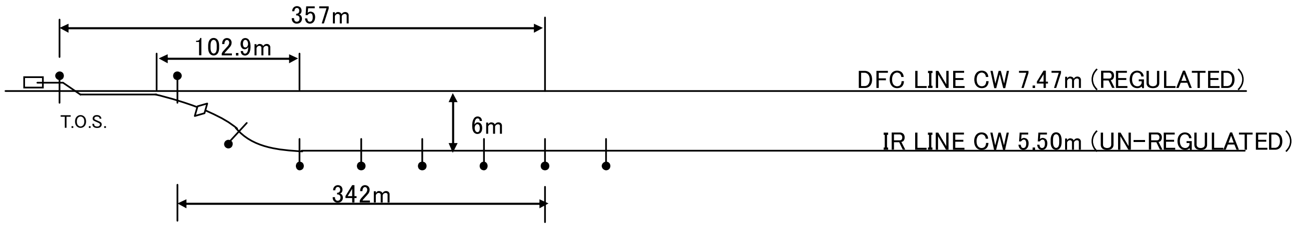
Two cases of transition (from 7530 mm of the DFC to 5600 mm of the existing line) were studied, as shown in Figure 5-9.

The first case (running at low speed of 30 km/h over the turnout) requires 367 m from the toe of turn out switch. The second case (running at high speed of 60 km/h) requires 870 m from the toe of turn out switch to move from the DFC to the normal IR running lines.

Figure 5-9 Studies on transition of OHE height

Minimum distance to Slope down OHE
from DFC Lines.(Contact Wire height 7.47m) & IR LINES (CW height 5.60m)

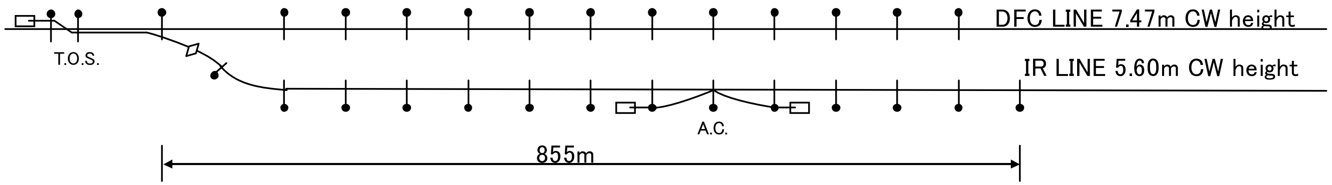
(a) YARD LINS MAX SLOPE ALLOWED 10mm/m, Transition 5mm/m



DISTANCE (m)	0	54	99	153	216	279	342	405	
SPAN (m)		54	45	54	63	63	63	63	
CW height (m)	7.47	7.47	7.25	6.62	6.00	5.70	5.50	5.50	
SLOPE (mm/m)		0	5	10	10	5	3	0	

TOTAL DISTANCE TO BRING DOWN CONTACT WIRE 351m From CENTRE OF TURN OUT 351m (366.5m from T.O.S.)

(b) HIGH SPEED LINES MAX SLOPE ALLOWED 3mm/m, Transition 1.5 mm/m



DISTANCE (m)	0	54	99	162	225	288	351	414	477	540	603	666	729	792	855	
SPAN (m)		54	45	63	63	63	63	63	63	63	63	63	63	63	63	
CW height (m)	7.47	7.47	7.41	7.23	7.05	6.87	6.69	6.51	6.33	6.15	5.97	5.79	5.70	5.61	5.60	
SLOPE (mm/m)		0	1.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	1.50	1.50	2.85	

5.2.4 Conclusions

MMD of rolling stock were calculated for two cases: 6830 mm for the DSC on flat-type wagons, and 6230 mm for the DSC on well-type wagons.

OHE contact wire heights were calculated by adding distance for insulation, oscillation, erection tolerance and pre-sag. The minimum clearances for ROB under electrification were calculated as 7.76 m for the DSC on flat-type wagons, and 7.16 m for the DSC on well-type wagons. They are not much different from the clearances contained in report of RITES.

The existing pantographs can be used for through operation between the existing lines and the DFC lines adopting DSC on well-type wagons, or the wide range pantograph with less modification of locomotive's installation keeping the locking down height 4,150 mm.

For the DSC on flat-type wagons, an example of a European pantograph which has a maximum working range of 3100 mm and extension of 3200 mm was given. The pantograph allows 25 kV and 2,000A current collecting, which fulfil the design conditions required for the DFC lines.

The relationship between OHE and the pantograph was studied in view of the raising the OHE height from 5.60 m to 7.53 m. As the result of studies focusing on relative displacement of OHE and the pantograph, it is recommended that lateral allowances be reduced by 10% from the existing design criteria.

5.3 OPTIMUM TRACTION SYSTEM FOR THE WESTERN CORRIDOR

In their pre-feasibility report, RITES proposed that the traction system of the DFC be electrified for the Eastern Corridor and non-electrified for the Western Corridor. It is inferred that this proposal was made mainly in deference to the current traction systems of existing lines, with consideration for the inter-operability between the proposed DFC and the existing lines.

In general, the electrified traction system costs less to operate than the non-electrified traction system because of its better energy efficiency. However, it has higher capital costs. Therefore, the total cost of the electrified traction system will become lower than the non-electrified traction system as the transport demands and frequency of train operation increases more and more.

In this section, the suitability of an electrified traction system in the Western Corridor is studied from following three points of view.

1) Energy security of India, including the trend of oil/coal prices and power supply condition in the country.

2) The cost analysis and evaluation by using the FIRR and NPV.

3) Environmental evaluation from the viewpoint of CO_2 emission.

5.3.1 Viewpoint from energy security

(1) Consumption and domestic production

Primary energy consumption is increasing in conjunction with the economic growth of India. However, Indian domestic crude oil production fulfilled only 8.3% of total demands in 2005-06, as shown in Figure 5-10. The Indian government is proceeding with its development of hydrocarbon fuels, including natural gas. Currently these fuels can merely meet the demand only to the extent of (almost equal amount of) quantity of domestic petrol consumption.

A large part of the domestic energy source has to depend on hydro and coal power generation. The price of crude oil is increasing along with the high growth rate of the economy and automobile usage in the BRICK countries. It appears that the trend towards higher crude oil prices will not change over the mid-to-long term period. At the same time, securing a stabilized source of crude oil becomes a high national priority for every country.

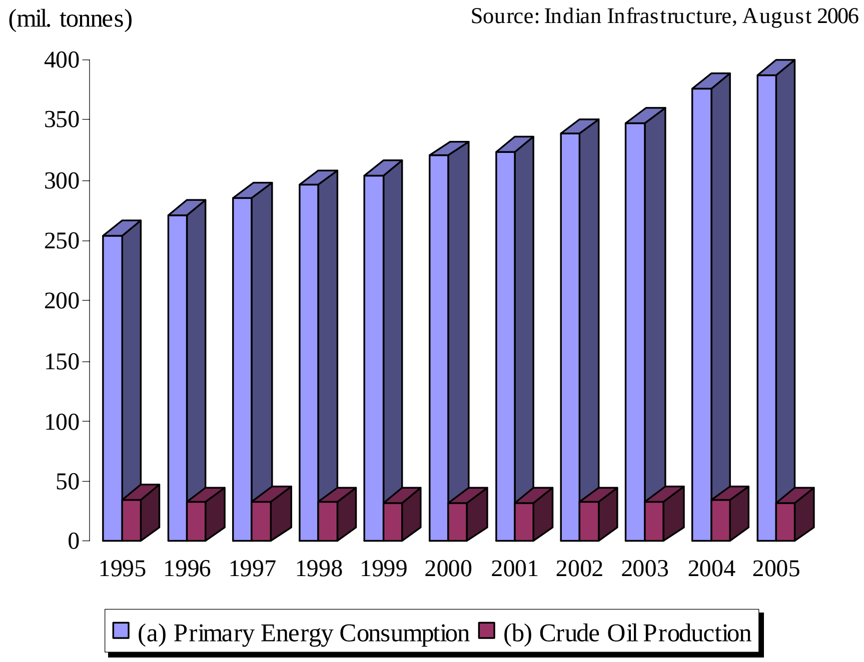


Figure 5-10 Primary energy consumption and crude oil production in India

(2) Trend of crude oil price

Figure 5-11[2] shows the trend of crude oil price increases over the past five years. The same increasing tendency can be seen in Figure 5-12, which shows a longer term. The peak price in the early 1980's was caused by the Iran-Iraq War.

[2] Figure 5-11 and Figure 5-12 are reprinted from "History and Analysis – Crude Oil Prices," *WTRG Economics Report*, Dec. 2005

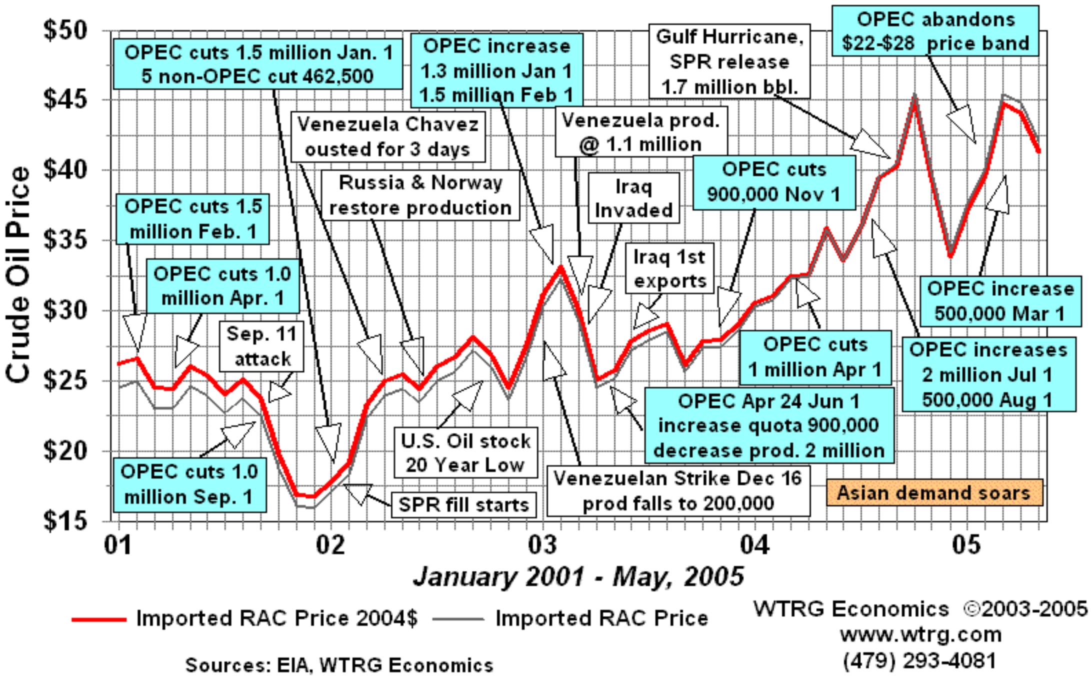


Figure 5-11 Crude oil price 2004 in US$ & Nominal

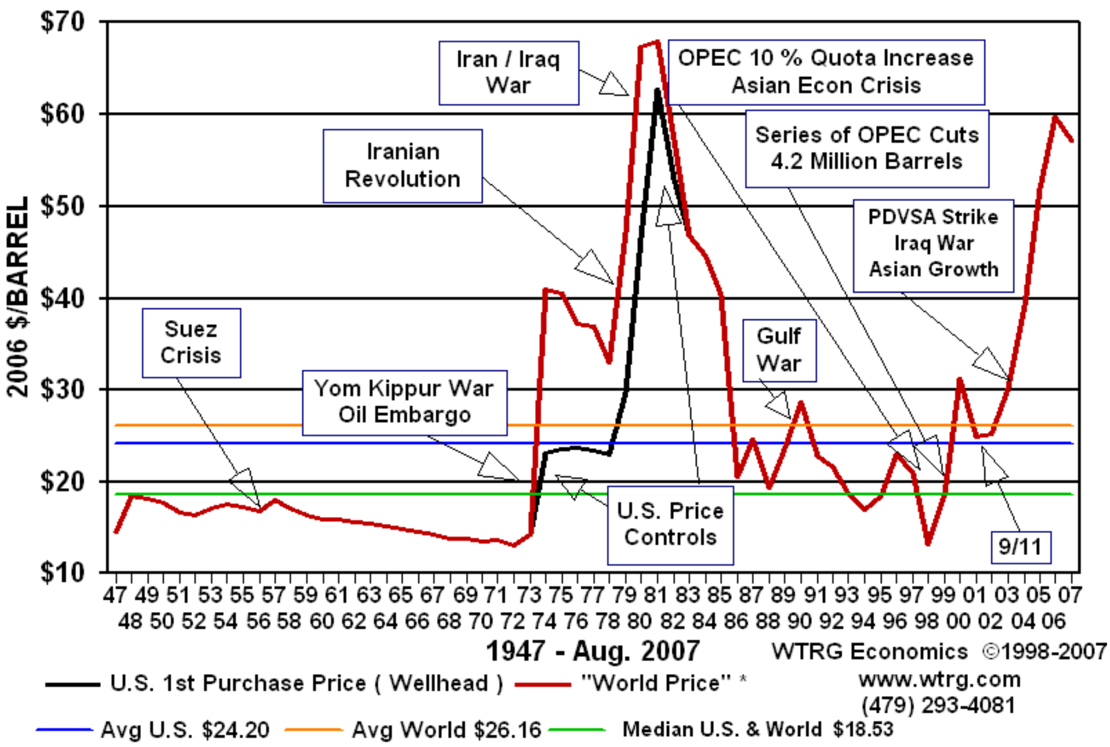


Figure 5-12 Crude oil price 2006 in US$

However, more recent high-pitched price increases are the result of economic growth in India, Brazil, China and other emerging countries. It is difficult to expect that crude oil prices will decline in the future.

Therefore, considering the apparent trend towards increasing crude oil prices, it would not be favourable for the traction system of the DFC to be dependent upon diesel fuel. Accordingly, it would be desirable to adopt electric traction, which enables energy to be readily obtained from a variety of sources.

(3) The present state of electric power supply

As shown in the, thermal power plants account for a large share of the electric power supply in India. According to *Governmental Statistics, September 2006*, coal power generation makes up 66 % of the total electric power generation. The total amount generated is 69,200 MW.

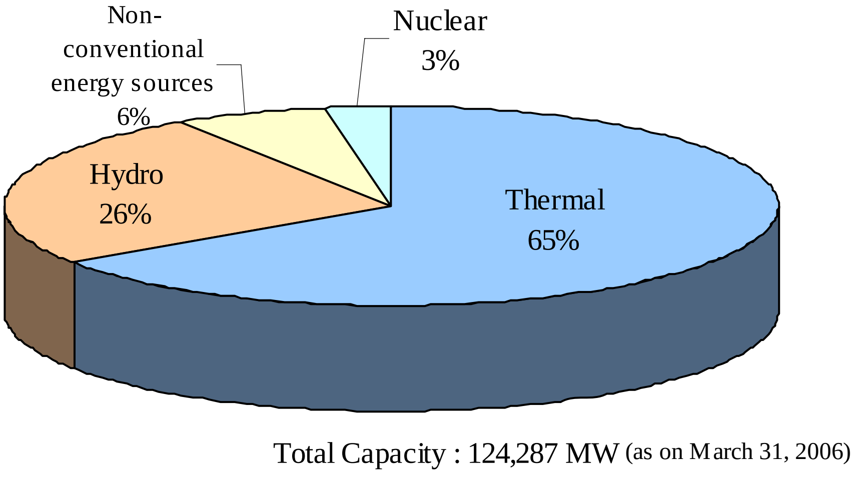
The Ministry of Energy has announced that it will make efforts to improve the capacities of hydro and thermal plants through a 10-year plan. A project to improve production by 19,000 MW completed and started service in year 2006-07. Projects for adding an additional 40,000 MW are under construction and are scheduled to start service during the period 2007-2010[3].

CEA (Central Electric Authority) is making plans to develop 70,275 MW, including thermal and hydraulic power. Regard with the Western DFC Corridor, thermal power of 15,245 MW and hydraulic power of 980 MW are planned. Electric power demand on the Western DFC Corridor is estimated as shown in Table 5-16, according to the transport planning in the case of electrification. This will be 116 MW in 2013 and 492 MW in 2031. Therefore, the electrification of the Western Corridor does not affect the total electric power supply.

Table 5-16 Electric power demand estimates on the Western DFC Corridor

	million GT km/day			Electric power	Power demand
	Bulk	Container	Total	MWh/day	MW
2013	239.8	97.8	337.6	2,529	126
2018	380.7	278.2	658.9	4,935	247
2023	440.1	407.6	847.7	6,349	317
2028	498.0	550.0	1,048.0	7,850	392
2031	537.0	598.8	1,135.8	8,507	425

Energy consumption based on Western Railway in 2004/05; 7.49kWh/1,000 GT km
One day couted as 20 hours



Source: India Infrastructure, August 2006

Figure 5-13 Power generation capacity by plant type

[3] Interview with R.V. SHARI, Secretary, Ministry of Power、*Indian Infrastructure*, Aug. 2006

(4) Trend of coal prices

From the above, it is clear that electric power generation in India is dependent upon coal. So do the same anxieties about the supply coal exist? The answer is clearly, no.

Both domestic and imported coal is used for the thermal power plants. Because of transport considerations, coastal power plants use mainly imported coal while the inland plants use mainly domestic coal. India imported 11 million tonnes of coal in 2005, which is the equivalent of 17 million tonnes of domestic coal when adjusted for caloric value.

International coal prices are more stable than oil prices, as shown in Figure 5-14[4].

The coal-supplying countries, such as Australia, are relatively politically stable countries, so there is less reason to be anxious about maintaining a steady supply of coal.

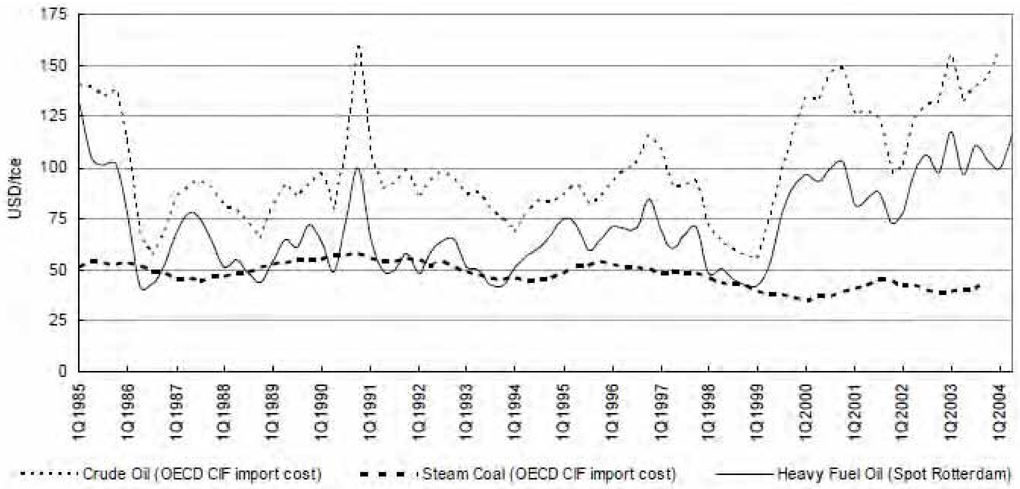


Figure 5-14 OECF international trade values for steam coal and oil

5.3.2 Economics of traction

We conducted a financial analysis of the traction system on the Western Corridor using such data and sources as the present transport plan, which is estimated based on demand forecasting; the energy and maintenance costs of locomotives, as obtained from the *Annual Statistic Statements 2004-05*; and the estimated prices of locomotives and based on the construction of electric facilities, such as electrification costs for the Eastern Corridor which were found in the *RITES Report* and other sources.

The objected/related cost items used in this financial analysis are:

1) Electrified Traction System

- Capital Cost (EL, Electrification Facilities and Re-building of ROBs)
- Maintenance Cost (Maintenance of EL and Electrification Facilities)
- Operation Cost (Fuel Cost)

2) Non-Electrified Traction System

- Capital Cost (DL)

[4] Steam and coking coal prices, Larry Metzroth, Principal Administrator, Energy Statistics Division, International Energy Agency, 3rd Quarter 2004

- Maintenance Cost (Maintenance of DL)
- Operation Cost (Fuel Cost)

Other cost items such as wagons and personnel cost of operators were assumed to be equal regardless of the traction system and were hence excluded from this analysis. The growth rate of transport demand and number of trains are followed by the results of Chapter 4 and 6.

The container stack option is assumed to be 50% of SSC and 50% of DSC.

(1) Cost of locomotives

1) Energy cost

Energy consumption and the costs on Zonal Railways related to the Western Corridor were calculated and are shown in Table 5-17 based on data obtained from the Tables 27(A), 27(B) and 38 in the *Annual Statistic Statements 2004-05*. Note that the energy cost of electric traction becomes 53% that of diesel traction when viewed in terms of distance-weighted average energy cost.

Table 5-17 Energy consumption and energy cost

		Consumption per 1,000 GT. km Litre or kWh*	Unit price Rs./litre or kWh**	Energy Cost Rs./ 1000GT. km
Diesel electric locomotive	Central	3.03	28.42	86.11
	Western	2.57	28.67	73.68
	North Western	2.12	25.12	53.52
	Northern	2.10	22.33	46.89
	Distance weighted average of each ZR***			62.80
Electric locomotive	Central	8.52	4.04	34.42
	Western	7.49	4.73	35.43
	North Western	NA	NA	NA
	Northern	5.70	4.20	23.94
	Distance weighted average of each ZR			33.44

* Column 18 in Table 27(B) in the *Annual Statistic Statements 2004-05*, GT. kms: Gross Tonne kilometres
** Column 68 and 74 of Table 27(A) in the *Annual Statistic Statements 2004-05*
***CR: 70 km JNPT/Vasai Rd., WR: 600km Vasai Rd./Palanpur, NWR: 633 km Palanpur/Rewari, NR: 133 km Rewari/Dadri in the *Annual Statistic Statements 2004-05*

2) Maintenance cost

Maintenance costs for locomotives were obtained from Table 30 in the *Annual Statistic Statements 2004-05* and are shown in Table 5-18. Note that the maintenance cost of electric locomotives is shown as Rs. 7.18 per 1,000 GT, which is lower of 55 % of the maintenance cost of diesel locomotives.

Table 5-18 Maintenance cost of locomotives

(Unit: Rupees per 1000 GT. km)

		Running Repairs in Sheds	Running Repairs in Workshop for Sheds	POH, IOH & Special Repairs*	Other Repairs*	Total
Diesel electric locomotive	Central	4.35	0.48	10.03	3.07	17.93
	Western	16.25	0.47	7.07	0.05	23.84
	North Western	0.97	0.08	0.96	0.00	2.01
	Northern	7.07	0.23	5.87	0.00	13.17
	Distance weighted average of each Zonal Railway					12.94
Electric locomotive	Central	6.43	0.45	3.59		10.47
	Western	4.65	0.02	0.95		5.62
	North Western	NA	NA	NA		NA
	Northern	7.80	0.01	4.65		12.46
	Distance weighted average of each Zonal Railway					7.18

POH: Periodical Overhaul, IOH: Intermediate Overhaul
*Cost of POH, IOH, special repairs and other repairs include diesel-hydraulic locomotives

3) Estimation of locomotive price

The prices for newly developed locomotives for the DFC are estimated based on the present prices of WAG-9 6,000 HP electric locomotives and 4,000 HP diesel locomotives. Consideration was given to development costs and the differences in power. The estimated prices are Rs. 14.50 cr. for a 9,000 HP 6-axle electric locomotive, Rs. 21.2 cr. for a 12,000 HP 8-axle electric locomotive, and Rs. 13.0 cr. for a 5,000 HP diesel locomotive.

4) Numbers of locomotive

In this analysis, it is assumed that the existing locomotives shall be utilized in the DFC, and 10% of the required number of locomotives in the opening year of the DFC shall be procured in that year. After that, 10% of existing locomotives shall be replaced by new ones every year. Furthermore, the incremental freight shall be transported by new locomotives which shall be procured every year against the demand. The 10% of locomotives in operation shall be additionally procured as the maintenance reserve.

Table 5-19 shows the number of locomotives that will be in operation and in reserve as of 2023-24. The estimate was made based on the demand forecasting for traffic volume and growth rate shown in Table 5-20.

Table 5-19 Numbers of locomotives in operation in Year 2023-24

			Electric loco	Diesel loco
Demand (10^9 Net ton km)	Container		72.40	
	Bulk		21.90	
Number of Locomotives	Locomotives in operation	Container	202	236
		Bulk	59	112
	Total		261	348

Table 5-20 Growth rate of freight demand

Year	Growth Rate per Annum	
	Container	Bulk
2013/14 – 2018/19	28.8%	10.1%
2018/19 – 2023/24	8.6%	1.8%
2023/24 – 2028/29	6.1%	1.9%
2028/29 – 2031/32	4.0%	1.9%
2031/32 -	0.0%	0.0%

(2) Cost of electric facilities

The cost of electric traction facilities for the JNPT-Ahmedabad section (569 km) and the Ahmedabad-Dadri section (899 km), a total of 1,468 km, was shown to be Rs. 0.50 cr. per km, according to the *RITES Report on the Eastern Corridor*. However, the plan at the first stage was to use the existing substations along the DFC route to supply electric power to the DFC lines. The costs for new substations and transmission lines were thus not included. However, in order to provide a full cost estimate, the estimated costs related to these facilities are shown in Table 5-21. This assumes the introduction of a 2x25 kV AT system and the positioning of a substation every 50 km along JNPT- Ahmedabad-Dadri section.

Maintenance costs of these electric facilities are estimated to be 2% of the construction cost annually, with major maintenance costing 10% every 10 years.

Table 5-21 Cost of electric facilities related to the Western Corridor

(Unit: *Crore Rs.)

	Unit cost	Quantity	Total cost
Electrification cost*	0.54	2,936 Tkm	1,610.31
Re-building of ROBs	0.76	535	406.60
Total			2,016.91

Note: Includes Rs.806 crores for 31 traction substations and associated transmission lines.

(3) Financial analysis

Table 5-22 shows the results of the financial analysis based on the conditions presented above, including the additional cost of flyovers caused by electrification. The result of an IRR of 24.4% and Net Present Value (discount rate = 12%) of Rs. 959.8 Cr. demonstrates that electrification is feasible and more economical under these conditions.

The results of sensitivity analysis (-50% to +50%) on traffic demand and diesel fuel costs are shown in Table 5-23. In regards to the traffic demand, electric traction is favourable even if the demand stayed at 50% lower than forecast. For diesel fuel costs, diesel traction will be favorable in case of 25% cheaper fuel price. Sensitivity analysis on electrification costs has been taken up to examine the effect of sensitive variables and to make sure that the results arrived at for electrification is favourable in all reasonable variables in inputs.

Table 5-22 Financial analysis of optimum traction system in Western Corridor

No.	Year	Transport Plan (10^9 Gross.ton.km)					Electrification Cost							Dieselization					Present Worth			
		SSC Only	DSC+SSC(EL)		DSC+SSC(DL)		ROB	Electric Facilities		Locomotive			Total	ROB	Locomotive			Total	Discount	Electrification	Dieselization	Total
		Cont.	Cont.	Bulk	Cont.	Bulk	Construction (Crore Rs.)	Capital (Crore Rs.)	O&M (Crore Rs.)	Procurement (Crore Rs.)	Fuel (Crore Rs.)	Maintenance (Crore Rs.)	(Crore Rs.)	Construction (Crore Rs.)	Procurement (Crore Rs.)	Fuel (Crore Rs.)	Maintenance (Crore Rs.)	(Crore Rs.)	Rate (%)	(Crore Rs.)	(Crore Rs.)	(Crore Rs.)
1	2	9	10	11	12	13	14	18	19	24	25	26	27	28	33	34	35	36	37	38	39	40
1	2008-09						448.55						448.55	419.49				419.49	100.0%	448.55	419.49	(29.07)
2	2009-10						448.55						448.55	419.49				419.49	89.3%	400.49	374.54	(25.95)
3	2010-11						448.55						448.55	419.49				419.49	79.7%	357.58	334.41	(23.17)
4	2011-12						448.55	335.66					784.22	419.49				419.49	71.2%	558.19	298.58	(259.61)
5	2012-13						448.55	335.66					784.22	419.49				419.49	63.6%	498.38	266.59	(231.79)
6	2013-14	30.62	23.31	18.63	24.42	19.03	448.55	536.77	20.14	1,246.40	140.24	30.11	2,422.21	419.49	1,667.00	272.87	56.22	2,415.58	56.7%	1,374.43	1,370.66	(3.76)
7	2014-15	39.43	30.02	20.51	31.45	20.95	448.55	201.11	20.14	199.30	168.97	36.28	1,074.35	419.49	276.40	329.09	67.81	1,092.78	50.7%	544.30	553.64	9.34
8	2015-16	50.78	38.66	22.58	40.50	23.07	448.55	201.11	32.21	192.60	204.79	43.97	1,123.23	419.49	276.40	399.23	82.26	1,177.37	45.2%	508.09	532.58	24.49
9	2016-17	65.39	49.78	24.87	52.15	25.40	448.55		32.21	217.60	249.63	53.60	1,001.58	419.49	313.00	487.07	100.36	1,319.91	40.4%	404.52	533.09	128.57
10	2017-18	84.21	64.11	27.38	67.16	27.97	448.55		32.21	278.30	305.94	65.69	1,130.68	419.49	401.60	597.45	123.10	1,541.64	36.1%	407.74	555.93	148.19
11	2018-19	93.59	71.24	27.80	74.64	28.40			32.21	303.30	331.21	71.11	737.83		438.20	647.09	133.33	1,218.63	32.2%	237.56	392.37	154.81
12	2019-20	101.63	77.37	28.31	81.05	28.92			32.21	135.70	353.37	75.87	597.15		198.40	690.62	142.30	1,031.33	28.7%	171.67	296.48	124.82
13	2020-21	110.36	84.01	28.82	88.02	29.45			32.21	150.20	377.33	81.02	640.75		224.40	737.68	152.00	1,114.07	25.7%	164.47	285.96	121.49
14	2021-22	119.85	91.23	29.35	95.58	29.98			32.21	135.70	403.23	86.58	657.71		198.40	788.55	162.48	1,149.43	22.9%	150.73	263.42	112.69
15	2022-23	130.14	99.07	29.89	103.79	30.53			32.21	164.70	431.23	92.59	720.73		250.40	843.56	173.82	1,267.77	20.5%	147.48	259.41	111.94
16	2023-24	138.57	105.48	30.44	110.51	31.10			132.91	129.00	454.53	97.59	814.03		198.40	889.30	183.24	1,270.94	18.3%	148.72	232.20	83.48
17	2024-25	143.47	111.93	31.00	117.26	31.67			32.21	135.70	477.97	102.63	748.50		198.40	935.33	192.73	1,326.45	16.3%	122.10	216.37	94.28
18	2025-26	148.55	118.77	31.58	124.43	32.26			92.54	150.20	502.76	107.95	853.45		224.40	984.01	202.76	1,411.17	14.6%	124.30	205.53	81.23
19	2026-27	153.81	126.03	32.16	132.04	32.85			32.21	135.70	528.99	113.58	810.47		198.40	1,035.52	213.37	1,447.29	13.0%	105.39	188.20	82.81
20	2027-28	159.26	133.73	32.75	140.11	33.46			32.21	150.20	556.73	119.54	858.68		224.40	1,090.01	224.60	1,539.01	11.6%	99.70	178.69	78.99
21	2028-29	164.90	141.91	33.36	148.67	34.08			32.21	150.20	586.09	125.84	894.34		224.40	1,147.67	236.48	1,608.55	10.4%	92.71	166.75	74.04
22	2029-30	162.39	147.51	34.00	154.54	34.73			32.21	110.70	606.96	130.32	880.19		161.80	1,188.62	244.92	1,595.34	9.3%	81.47	147.66	66.19
23	2030-31	159.92	153.33	34.65	160.64	35.39			32.21	85.70	628.60	446.57	1,193.08		125.20	1,231.11	670.42	2,026.73	8.3%	98.60	167.49	68.89
24	2031-32	157.48	159.39	35.31	166.99	36.07			32.21	110.70	651.06	189.62	983.59		161.80	1,275.19	331.85	1,768.84	7.4%	72.58	130.52	57.94
25	2032-33	157.48	159.39	35.31	166.99	36.07			32.21	110.70	651.06	187.94	981.91		161.80	1,275.19	331.85	1,768.84	6.6%	64.69	116.53	51.84
26	2033-34	157.48	159.39	35.31	166.99	36.07		(161.03)	132.91	(2,350.91)	651.06	194.19	(1,533.78)		(3,621.33)	1,275.19	341.00	(2,005.14)	5.9%	(90.22)	(117.95)	(27.73)
								1,449.28	913.93	4,181.90	7,959.62	2,040.35	21,056.63		5,961.40	15,569.95	3,637.83	29,420.25	12.00%	7,294.21	8,369.15	959.77

FIRR= 24.38%
NPV= 959.77 Crore Rs.
B/C= 1.15

Table 5-23 Sensitivity analysis on transport demand and diesel fuel cost

			Fuel Cost of Diesel Oil				
			50%	75%	100%	125%	150%
Transport Demand	50%	FIRR (%)	-	7.3%	14.2%	19.1%	23.1%
		NPV (Crore Rs.)	-573.8	-220.3	133.2	486.7	840.2
	75%	FIRR (%)	-	12.3%	19.8%	25.6%	30.53%
		NPV (Crore Rs.)	-514.0	16.3	546.5	1,076.7	1,606.96
	100%	FIRR (%)	-	16.0%	24.4%	31.0%	36.8%
		NPV (Crore Rs.)	-454.2	252.8	959.8	1,666.8	2,373.7
	125%	FIRR (%)	0.1%	19.1%	28.4%	35.9%	42.5%
		NPV (Crore Rs.)	-394.4	489.3	1,373.1	2,256.8	3,140.5
	150%	FIRR (%)	3.6%	21.9%	32.1%	40.4%	47.6%
		NPV (Crore Rs.)	-334.6	725.9	1,786.3	2,846.8	3,907.3

5.3.3 Evaluation from environmental aspects

Comparisons of energy efficiency between electric and diesel traction are shown in Table 5-24. Additionally, CO_2 gas emissions are calculated for each mode of transportation.

The energy consumption of diesel passenger trains is 2.6 times greater than that of electric passenger trains. A diesel freight train will consume 3.0 times more energy than an electric freight train. Additionally, the CO_2 gas emissions of diesel passenger trains is 1.6 times of electric passenger trains, while the CO_2 gas emissions of diesel freight trains is 1.9 times more than that of electric passenger trains.

It is clear that electric traction also offers superior energy efficiency and lower CO_2 gas emissions over diesel traction.

Table 5-24 Comparison between diesel & electrical locomotive energy efficiency

		Energy Consumption			CO_2 Emission	Electric/Diesel
		(BTU*)	(kcal)	(kWh)	(kg-CO_2)	
Passenger	Diesel	170.20	43	0.050	0.010	1.00
	Electric	64.60	16	0.019	0.006	0.60
Freight	Diesel	255.50	64	0.075	0.015	1.00
	Electric	84.60	21	0.025	0.008	0.53

Obs: Energy consumption and CO_2 emission to move 1 ton of traffic over 1km
*1BTU (British thermal unit) = 0.252 kcal; 1 kcal = 0.00116 kWh; Electricity (coal): 1kWh = 0.32 kg-CO_2; Diesel: 1kWh = 0.2
Source: *S.R. Chuadhuri, Indian Railways, January 2006 (Power Losses included)

5.3.4 Conclusions

With regards to the interoperability between the DFC line and the existing lines, diesel locomotives can be operated on the DFC line even when the DFC line is electrified. Diesel traction on an existing line should thus not be a hindrance for the electrification of the DFC. Also, as the reconstruction of existing ROBs and OHE shall be needed (although at lower height) even for diesel traction, the issue is not of overriding importance against electric traction on the DFC.

As mentioned above, it seems risky to adopt diesel traction on the Western Corridor, depending on petroleum only when India can fulfil less than 10 % of its total primary energy consumption, which is increasing in conjunction with economic growth, by its domestic crude oil. It appears that the trend towards higher crude oil prices will not change over the mid-to-long term period. Consideration of energy security related to trends of price increases of crude oil and coal, and the need to secure energy sources lead to the conclusion that electric traction should be favoured.

Anxieties also remain regarding the profitability of the project when major parts of the traction system of the DFC are dependent on diesel fuel, which contain potential for higher prices. On the other hand, electric traction uses various primary energy sources.

The energy cost of electric traction is 53% that of diesel traction at the present. Considering that crude oil prices are likely to increase continuously in future, it seems very hard to expect that the energy costs of diesel traction will ever become less than that of electric traction. Also, the total energy consumption of the electric traction is less than that of the diesel traction in long-mid term.

The maintenance cost of electric locomotives is 55 % of that of diesel locomotives. Therefore total operating cost of electric traction including energy cost remains significantly less than that of diesel traction.

With regards to the construction of the DFC line, results of financial analysis show superiority of electric traction even for a new line. Total savings of Rs. 8,363.6 Cr., an FIRR of 24.4%, and an Net Present Value (discount rate = 12%) of Rs. 959.8 Cr. demonstrates that electrification is feasible and economical under these conditions. By sensitivity analysis of traffic demand and diesel fuel costs, maintenance costs and electrification costs, every case (only except if oil prices go down by 25%) points in favour of electric traction.

Evaluation on CO_2 gas emissions also concludes that electric traction is more environmental friendly than diesel traction.

Therefore, as mentioned above, JST recommends the electrification of the Western Corridor from various viewpoints such as energy security, energy costs, maintenance costs, financial analysis and environmental aspects.

5.4 STUDY OF DOUBLE COUPLED TRAIN PLAN

5.4.1 Purpose of this study

As indicated in the previous section, the line capacity can be enhanced without a huge facility improvement investment by replacing single-stack container trains with double-stack container (DSC) trains. Unfortunately, bulk wagons cannot be double-stacked, so the *RITES PET-II* proposed the Double Couples Train (DCT) Plan by which two trains are coupled together and operated as if they were a single train.

In this section the need for operating DCT, the viability for implementing DCT from a technical viewpoint and the potential profit and loss of DCT from the financial viewpoint is discussed.

5.4.2 Needs of operation of DCT to meet the demand

In the Eastern DFC, where most of the freight trains are bulk trains, the maximum number of trains in the most congested section is forecast to be 1 is 103 in 2033-34trains in fiscal year 2033-34. This figure is lower than the 140 trains/day/direction of the line capacity for of the

DFC (See Table 5-25). Accordingly, there will be no requirements to operate DCT in the Eastern DFC.

Table 5-25 Number of Trains in by sections Sections (Eastern DFC)

Section		Year 2033-34
Sonnagar Jn	Mughal Sarai Jn	91.7
Mughal Sarai Jn	Cheoki	83.4
Cheoki	Prempur	86.9
Prempur	Bhaupur	93.2
Bhaupur	Tundla	103.5
Tundla	Daud Khan	93.7
Daud Khan	Khurja Jn	89.4
Khurja Jn	Dadri	51.1

If DSC trains are used in the Western DFC, where the ratio of container trains is relatively large in relation to the total number of trains, the line capacity can accommodate the entire demand forecast for fiscal year 2033-34.

Looking at the results above, the need for operating DCT would not arise until much later than 2033-34.

5.4.3 Operation of the DCT

The following summarizes the train control for DCT and the operations at the station.

1) Braking of trains

These wagons have an automatic air brake system. In this system, when the brake is applied in the cabin, the pressure in the train air pipe is gradually reduced as the braking action is performed because it takes time for the air pressure in the rear-most wagons to be reduced. Because of this, the DCT configuration would not quickly reduce overall braking pressure.

Countermeasures to overcome this lack of brake performance will be necessary when using the DCT configuration, and they will increase the procurement cost of the rolling stock.

2) Operation at stations

The longer the length of a loop at a station, the more time it will take to walk to the end of that loop. For example, if someone maliciously placed a stone between the tongue rail and the main rail that caused a turnout to malfunction, it will take time for the station staff to walk to that area and correct the problem. This time adds to the recovery time.

5.4.4 Rolling Stock Performance

(1) Traction

DCT operation has been proven around the world. There is much information about how to compose a long train in order to best distribute its traction powers. Railways in the United States, Australia, Brazil and other countries in South America have much experience on the matter. Often the locomotives are positioned at the head, middle and end of the train to equalise the traction effort and reduce the stress on the couplers. In these long trains with multiple locomotives, the control of the remote locomotives and electric command air brake systems can be done through a wire connection or by radio (wireless connection). The wireless radio systems may experience transmission problems in tunnels and other covered infrastructures. Such transmission problems can be rectified by using leaky coaxial cable (LCX) along the line in these problem areas.

The JST recommends the use of wire for the connections because it offers reliability and shorter braking distances. A comparison of both systems is shown in Table 5-26. A detailed examination is provided in the next section. Note that a wireless radio system cannot be used to synchronise the braking of the wagons; it only controls the brake operation in the locomotives. The stopping distance is longer than with a wired system. The shorter braking distances come from faster brake response time.

Table 5-26 Comparisons of Both Types of Remote Control Systems

Items	Remote Control System by Radio	Remote Control System by Wire
Transmission	Commands and data exchanges are done by radio.	Commands and data exchanges are done by wires through train.
Merits	No installation on wagons is required.	Transmission reliability is higher than radio. No dedicated frequencies are required. As wires can synchronise the braking of the wagons, shortening stopping distances and to reducing force on the couplers, avoiding derailment.
Demerits	LCX or other facilities are needed to transmit commands in tunnels or covered area. It is required to provide dedicated frequencies for the transmission. As the system cannot synchronise wagons' braking, so the stopping distance is longer than with a wired system.	Wagon costs are increased -- both initial and maintenance costs. Vandalism of the wire can interfere with train operations.

(2) Braking performance

While the automatic air brake system contributes to safe train operation, it requires a long response time when used on a long train. This means that a long train will require a longer overall stopping distance than a short train. Additionally, under exceptionally bad conditions, derailments have been attributed to the shock forces between couplers created when emergency braking is applied on an automatic brake system. Even when systems using remote control by radio are introduced, they alone cannot solve these innate problems of the automatic air brake system.

The electric-command brake system and the electro-magnetic command automatic air brake system (ARE) were developed to solve these problems and to synchronize the braking force of each of the wagons to increase overall braking force.

With the electric-command air braking system, there is a main reservoir air pipe that passes from the locomotive through the train to supply the compressed air to the brakes on each wagon. However, the signals for operating the brakes are sent electrically by command lines that also extend the entire length of the train. These electric command signals actuate electro-magnetic valves on the wagon that control the supply of compressed air to the brake cylinders, thereby controlling the brakes. Because there is the flow of electricity through the command lines, this system can also allow for the detection of wagon separation during operation, which can be used to activate emergency braking. The system has been used on heavy freight trains in the United States and for high-speed and EMU trains in Japan. The electric command air brake system is not compatible with the automatic air brake system.

Wagons with the electro-magnetic command automatic air brake system can be coupled to wagons with the automatic air brake system. In this case the electromagnetic command automatic air brake wagons can be used as the automatic air brake system. It is designed so that the main reservoir pipe and the electric command lines are routed through the train in parallel with the brake pipe for the automatic air brake system. This allows the system to be used as a conventional automatic air brake system by controlling the air pressures from the driving cabin without the use of the command lines. The command signals can also be used to actuate the electro-magnetic valves on the wagons to supply or release compressed air into brake cylinders for controlling braking force in conjunction with automatic air brake valve operation.

Improvement of braking system is recommended for high-speed and heavy freight train operation. However, at the time of selection of the braking system, it is important to examine the compatibility or mixed usage of any new brake system with that of the existing system.

The effect of the ARE system is shown in Figure 5-15. The assumptions used in the calculation are as following.

The long train is a 1,500 m DCT using a conventional brake system.

The short train is 750 m train using the conventional brake system.

The ARE train has an electro-magnetic command automatic air brake system.

The response times of the conventional brake system are 25 seconds for the short train, 50 seconds for the long train.

The response time of the ARE brake system is 3 seconds regardless of train length.

The longer response times are because of the longer stopping distances. The detailed studies are provided in *Volume4 Technical Working Paper Task2, 5-(5)*.

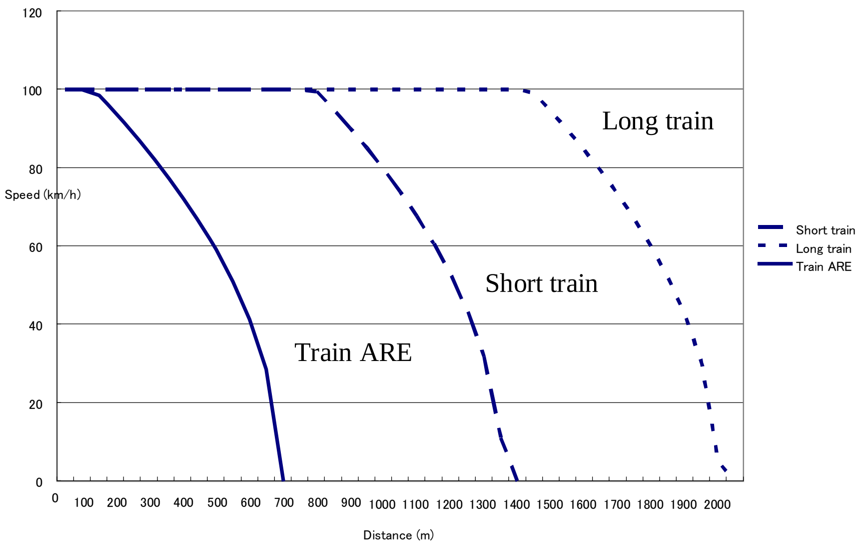


Figure 5-15 The Effect of the ARE System

(3) Train operation time

A longer train requires longer time for restarting. This is because each wagon has a 200 litre air reservoir that is used for braking operation. Therefore a long train will require more than six minutes instead the three minutes for a conventional length train to fill the air reservoirs and air pipes.

5.4.5 Line capacity

The length of the loops in stations will be doubled to accommodate DCT operation. The running time for the speed restricted section at the diversion of the turnout or stop signal will be extended according to the extension of the loop length and the train length. If the facilities can be provided on the precondition of DCT operation, the running time for the speed restricted section will be extended even for normal-length single trains. As the train length of a DCT is double that of a conventional single train, more time will be required for the tail of the DCT to pass through a speed restricted section.

The nature of line capacity is such that a crucial bottle neck section can determine the entire line capacity. So we selected a worst-case scenario in which only a single loop is used for the departure and arrival of trains at a station. From this, the headway was calculated and then an estimate was made of how much the extension of the loop length and the length of the train affected line capacity.

The location of two trains will be decided when the tail of the preceding train passes the start signal. At this moment, the succeeding train will enter the station as soon as it can, based on the proceed signal from the home signal. The headway can be calculated based on this train movement. The specific track and signal alignments near a station and the location of the two trains to be operated continuously are shown in Figure 5-16.

Precondition for study will be as follows.

1) When 1500 metre loops are used, the stopping point for a normal single train will be the same as that of DCT, which is 50 m short of the start signal.

2) The succeeding train will enter the station at the moment the yellow signal is displayed at the home signal following the departure of the preceding train. The indication of the home signal will be changed to the upper one as the preceding train moves. The brakes on the succeeding train will have already been applied and the engineer will enter the station as if the home signal still indicated the yellow signal.

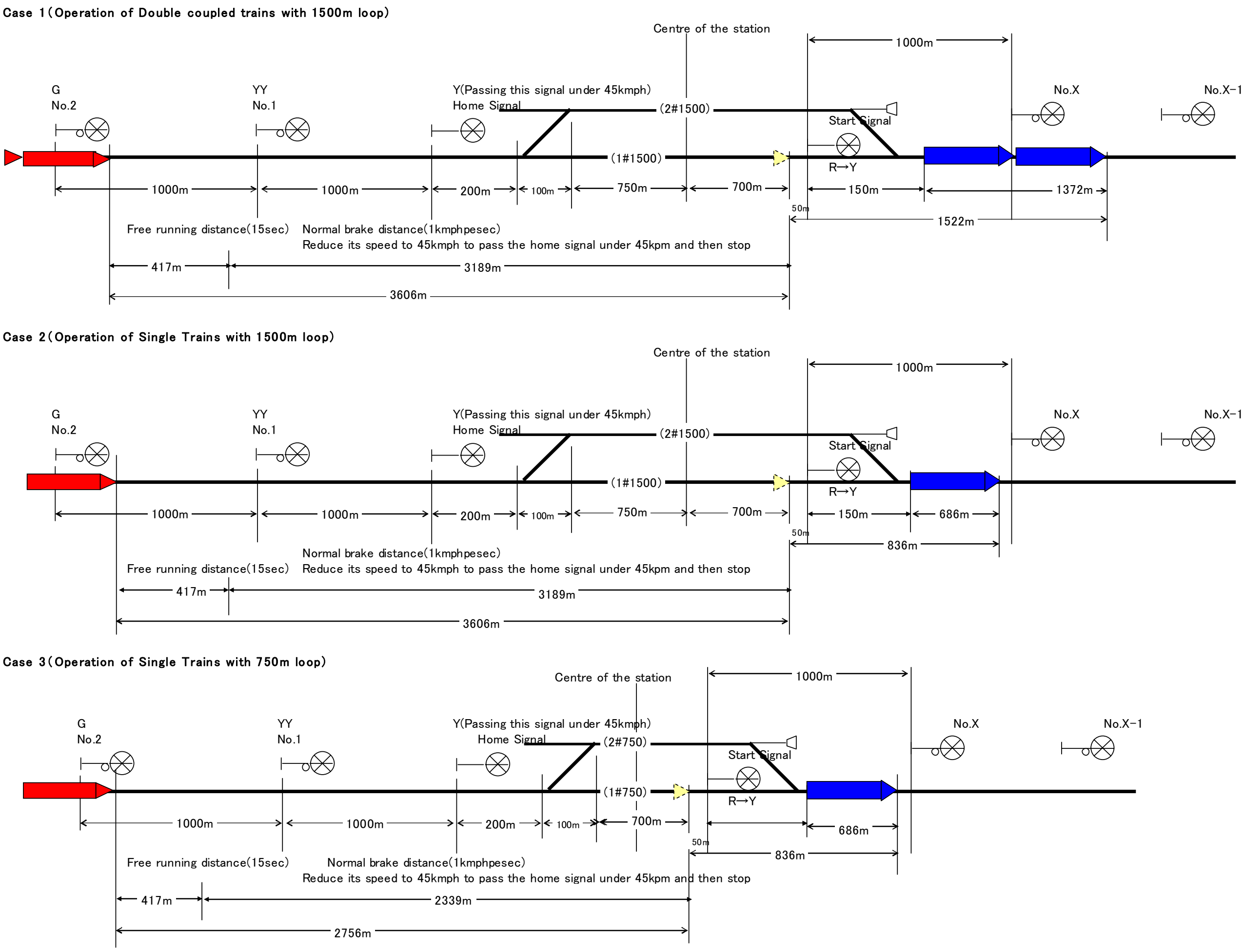


Figure 5-16 Track Alignment and the Location of Trains that Determine the Headway

The result of the calculation is shown in Table 5-27.

Table 5-27 Headways According to the Train Length in a Single Loop Operation (5800 tonne hauled per train)

Loop length	Headway with Single Trains (A)	Headway with DCTs (B)	Ratio (B/A)
1500m (C)	8 : 27	9 : 08	108
750m (D)	7 : 15	—	—
Ratio (D/ C)	117%	—	—

From these figures, the headway will increase by 17% if the loop length is extended to 1500 m when DCT operation is not required. As the headway is the inverse of the train number, the number of trains will be reduced to 86%. On the section with 750 m loops, the number of trains operated in the DCT configuration will decrease to 79% of the train number when a single train is operated.

5.4.6 Benefit and Cost Analysis

1) Increase of procurement cost of rolling stock

The cost of the rolling stock will increase by ten thousand USD per rolling stock. (In case of wagons, this is accounts for approximately 20% of the procurement cost of a new one.) Incidentally, in the project cost estimation, 70% of the required number of wagons are assumed to be met by using existing wagons in fiscal year 2013-14. In this estimation of the increase of the procurement cost for wagons, it is assumed that these existing wagons (4,751wagons) will be equipped with the new brake system. 42.98Rs/US$ is used as the exchange ratio of Rupees from US$. (See Table 5-28)

Table 5-28 Increase of Procurement Cost for the Additional Brake Function

Fiscal Year		Unit	2013-14	2018-19	2023-24	2028-29	2033-34
Number of locomotives for bulk trains			117	211	224	237	246
Number of bulk wagons			6,260	10,762	11,297	11,774	12,073
Increase in cost	Locomotives	Thousand US$	1,170	2,110	2,240	2,370	2,460
	Wagons	Thousand US$	62,600	107,620	112,970	117,740	120,730
Total		MRs	2,741	4,716	4,951	5,162	5,295

Note: MRs.: Million Rupees

2) Increase of construction cost

Investments for additional facilities required for the operation of DCT are the land acquisition cost for the loop extension and the cost of the track. The total cost for additional facilities is calculated based on the data from Table 5-29 to Table 5-31. Its result is 5,084MRs.

Table 5-29 Number of Stations

	Western Corridor	Eastern Corridor		Total	Remarks
	Double	Double	Single		
Terminal stations	3	1	1	5	
Crossing stations	31	15	8 (36)	54	One fourth of the stations on the single section will be equipped with 1500 m loops
Junction stations	10	10	3	23	
Total	44	26	12	82	

Table 5-30 Increase of Quantity and Cost per Terminal / Crossing Station

	Unit	Quantity	Unit price (Rs.)	Total (Rs.)	Remarks
Land acquisition	ha	6.56	2,450,000	16,078,125	Without compensation
Earth works	m^3	126,563	150	18,984,375	Without jungle clearance Without tree Plantations
Rail	km	1.50	6,853,038	10,279,557	Normal rail
Ballast	km	1.50	2,585,822	3,878,733	
Sleepers	km	1.50	2,702,951	4,054,427	
Blanket	m^3	11,250	500	5,625,000	
			Total	58,900,217	
			Number of stations	59	
			Total cost	3,475,112,774	

Table 5-31 Increase of Quantity and Cost per Junction Station

	Unit	Quantity	Unit price (Rs.)	Total (Rs.)	Remarks
Land acquisition	ha	6.56	2,450,000	16,078,125	Without compensation
Earth works	m^3	120,938	150	18,140,625	Without jungle clearance Without tree plantation
Rail	km	2.25	6,853,038	15,419,336	Normal rail
Ballast	km	2.25	2,585,822	5,818,100	
Sleepers	km	2.25	2,702,951	6,081,640	
Blanket	m^3	16,875	500	8,437,500	
			Total	69,975,325	
			Number of stations	23	
			Total cost	1,609,432,469	

3) Reduction of operation cost

As for the operation cost, DCT operation will cut in half the total personnel cost for engineers. The total amount of reduction will be 136 MRs per year for the entire DFC for fiscal years 2023-24, based on the average wage of employees of IR and adopted for the unit wages for engineers. (See Table 5-32) There are no other fluctuations in energy cost, maintenance cost for rolling stock or other such expenses. However, it is important to keep in mind that shunting for coupling/uncoupling of trains will be required at the terminals, which will require additional employees, so the overall reduction of the personnel cost will not be so large.

Table 5-32 Reduction of Wages for Engineers (Unit: MRs)

Fiscal year	2013-14	2018-19	2023-24	2028-29	2033-34
Reduction	70	128	136	143	148

4) Increase of revenue

DCT is not required from the demand. Accordingly there will be no increase of revenue.

5) Total Evaluation

Table 5-33 shows the increase of depreciation cost, the decrease of operation cost and the increase of revenue in fiscal year 2023-24. From this table the fact that the benefit with this project is significantly under the expenditure can be seen. It makes no sense for this investment from the financial viewpoint.

Incidentally, if a normal single train were to be operated on the section with 1500 m loops, the increase in cost would probably only be the depreciation cost for facilities, so there is no benefit. Hence it also makes no sense for this investment from the financial viewpoint.

Table 5-33 Affect on Profit and Loss by DCT Operation

Items		2023-24	Remarks
Increase of depreciation cost	Rolling stock	137.5MRs	Straight-line depreciation for 36 years
	Construction	127.1MRs	Straight-line depreciation for 40 years
Increase of cost		264.6MRs	
Reduction of operation cost （Employees cost）		136MRs	
Increase of revenue		0MRs	
Total benefit		136MRs	

5.4.7 Conclusion

There are some problems with the plan for 1500 m loops at stations

1) Based on the demand forecast, there will be no need for DCT until fiscal year 2033-34.

2) The line capacity of 140 trains per direction per day will be reduced by 14% if DFC were to open with 1500 m loops. And as the station yards become larger, it takes a much longer time to address the inevitable daily problems that will occur in them.

3) Locomotives and wagons with high performance brake systems will be required. Wagons will be equipped with special equipment so that closed headway operation will be required for these wagons.

4) Revenue will not increase even if DCT were to be operated on sections with 1500 m loops. As for the cost, depreciation may increase due to the increase of rolling stock cost and construction cost. The wages for the engineers will be reduced but the number of employees required for shunting operations at the terminals will also increase, so the total reduction of employee cost will not be significant. The benefit from the implementation of this plan would be 50% of the cost, so it would not make sense from a financial viewpoint.

   If a normal single train were to be operated on sections with 1500 m loops, there would be no increase of the revenue and no decrease of the expenditure, but the depreciation cost would increase. Accordingly, it would not make sense to carry out this plan from a financial viewpoint.

Based on the above, we cannot recommend that the plan to provide 1500 m loops from the beginning of DFC operation. However, it will become more difficult to procure the adjacent land of stations after the opening of DFC, so it would make sense to procure the land in a lump sum as this would enable the operation of DCT in future.

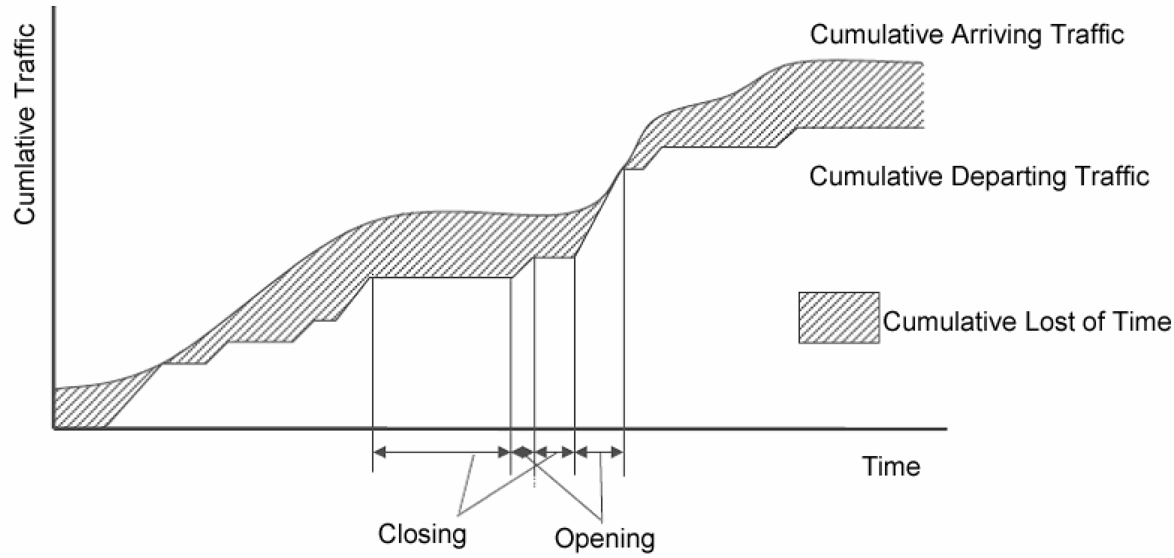
5.5 IMPROVEMENT METHOD OF LEVEL CROSSING

5.5.1 Economic loss by level crossing

(1) Basic concept of economic loss by closing of level crossing

This section aims to estimate the economic loss caused by the closing of level crossing. We will compare this with the cost of constructing ROBs (road over-bridges) to determine a guideline for the selection of improvement methods of level crossing.

A level crossing is closed when a train goes through it, which forces traffic on the crossing road to stop and wait until the crossing gate opens. The cumulative waiting time (which is a loss of time) is calculated and shown as the shaded areas in Figure 5-17 below. The upper curve represents the cumulative number of arriving vehicles at a level crossing, and the lower one represents the cumulative number of departing vehicles. When the left and right borders represent the beginning and the end of the day, respectively, the crossing point of the upper curve and the right border represents the total number of vehicles a day at the level crossing. The horizontal segments of the lower curve represent the situation where vehicles on the crossing road can not go through the level crossing due to the closing of the crossing barrier, and the sloping segments, whose gradient is equal to the capacity per time unit, represent the situation where vehicles can go through because of the opening of the crossing barrier.



Source: Cost-Benefit Analysis Manual (Railway Elevation Project), Ministry of Land, Infrastructure, and Transport Japan

Figure 5-17 Conceptual chart for cumulative time of the waiting time

As is clear from the figure above, loss of time by level crossing differs by arriving pattern even if the total traffic a day is the same. Since the arriving pattern varies from place to place, even if the daily traffic is the same, each level crossing causes different economic losses, and it is difficult to generalize the economic loss. In addition, vehicle composition also affects the estimation of economic loss because value of time is different depending on vehicle type. It is necessary to consider these factors when estimating economic loss at level crossings in this chapter.

(2) Estimation method and preconditions

The precondition of hourly arriving pattern of vehicles in a day is shown in the Figure 5-18 below. Constant arrival was assumed in each hour. It was assumed that there are morning and evening peaks on the road. If arriving vehicles overflow in an hour, the overflow was transferred to the next hour.

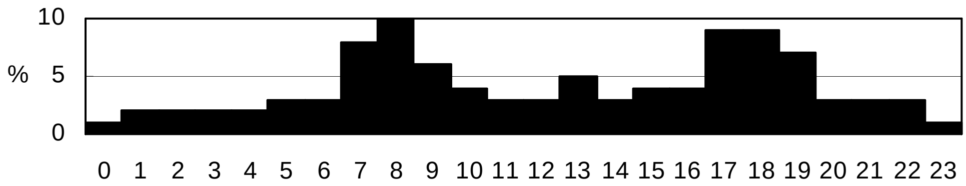


Figure 5-18 Hourly arriving pattern of Vehicle

Preconditions about the composition of vehicles, time value, and passenger car unit (PCU) are as follows. From this, the time value per PCU was set at Rs. 106/hour.

Table 5-34 Preconditions

	Car	Bus	Truck
Composition	60%	10%	30%
Time value (Rs/hour)	110	582.2	80
PCU	1.0	2.0	2.0

Capacity of a level crossing was set at 1800 PCU/hour/direction for a 2-lane road and 3,600 PCU/hour/direction for a 4-lane road. It was assumed that road traffic would increase at 3% per annum.

As to the precondition of the trains, the number of train was set at 80 trains per day per direction in the beginning (2013-14), increasing to 230 in 2031-32 (DFC + existing lines), and the numbers were divided by 24 to estimate hourly volume. The hourly closing time was estimated based on the assumption that the closing time of a passing of a train would be 2 minutes (with automatic level crossing control), as shown in Figure 5-19.

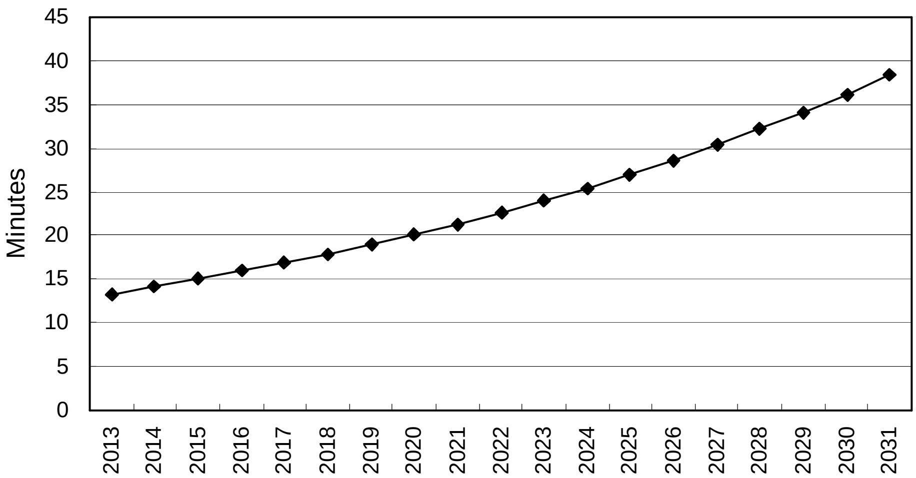


Figure 5-19 Hourly closing time

(3) Results of calculation

Economic loss for 25 years after the commencement of the DFC was calculated with a 12% discount rate as shown in the figure below. The number of days in a year was set to 360 in the calculations. In addition, another case was calculated for urban areas, with settings of 3 minutes closing time and buses at 20% (trucks at 20%) as shown in Figure 5-20 and Figure 5-21 below.

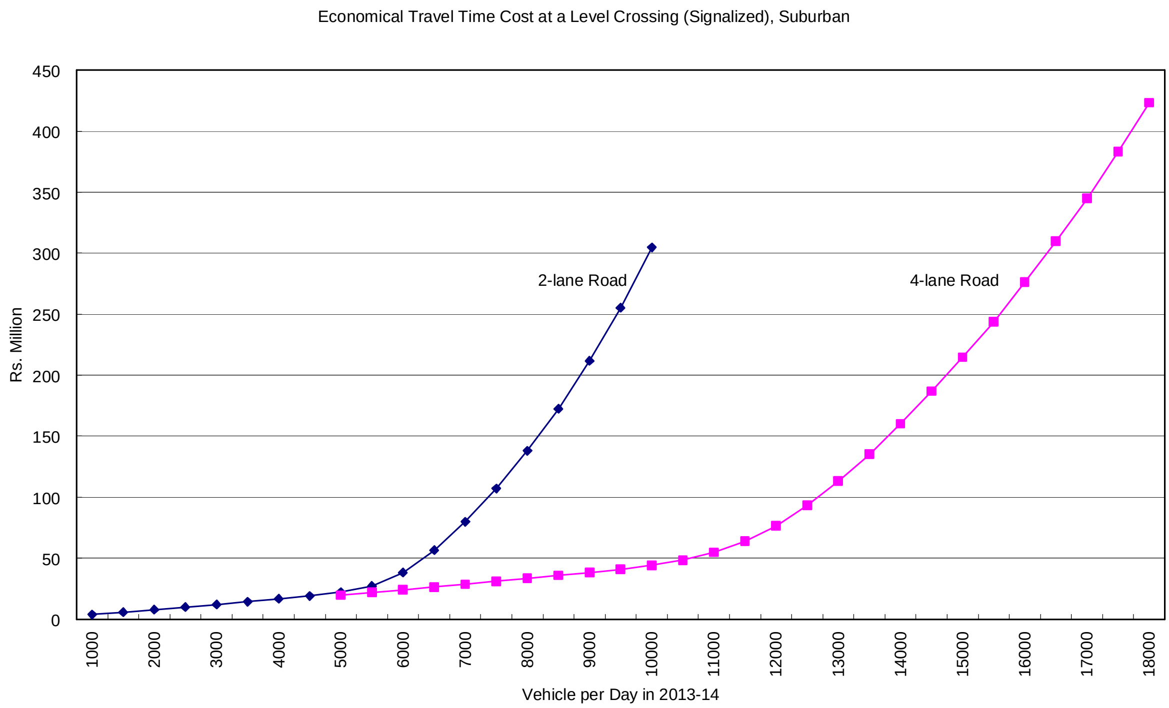


Figure 5-20 Economic loss at a level crossing (suburban)

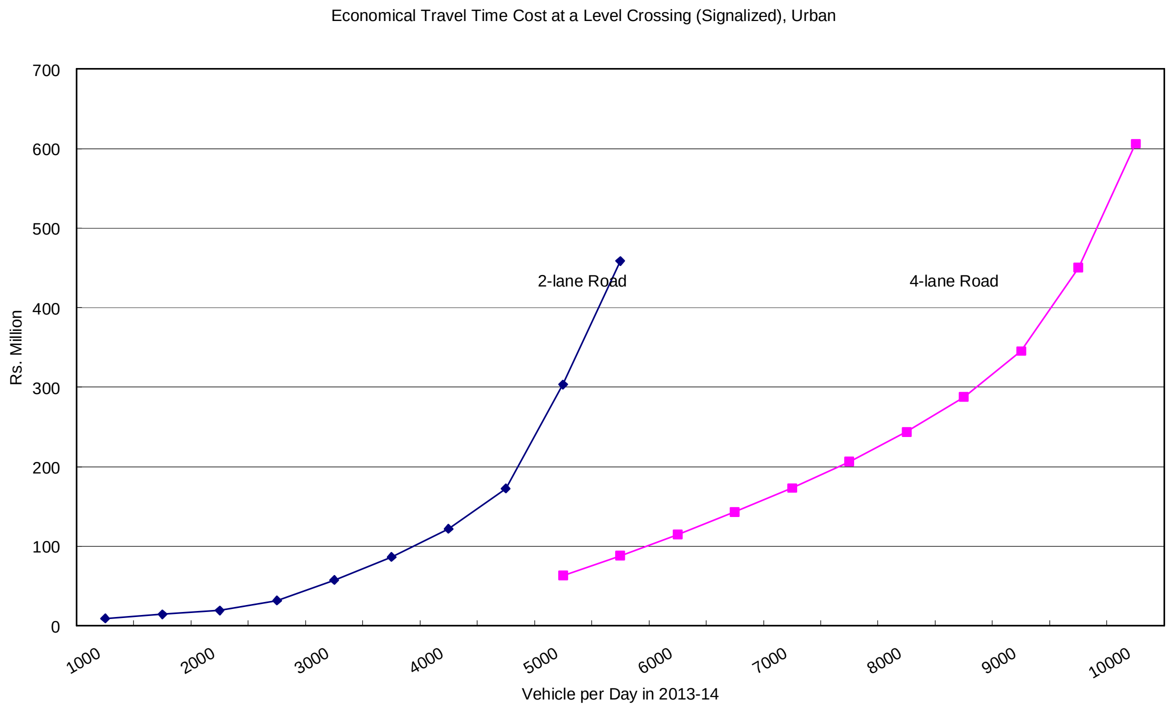


Figure 5-21 Economic loss at a level crossing (urban area)

Note 1: The number of trains was assumed not to increase after 2031.
Note 2: Economic loss near stations becomes greater because of the longer closing time

(4) Analysis of the result

A ROB in suburban areas costs about Rs. 77 million. Comparing this amount with the economic loss shown in Figure 5-20, ROB construction becomes economically better than a level crossing when the daily traffic in 2013-14 exceeds 7,000 vehicles at crossings with 2-lane roads. In the case of 4-lane road, is the break even point is 12,000 vehicles per day.

On the other hand, a ROB in urban area costs about Rs. 243 million. Comparing this amount with Figure 5-21, ROB construction becomes advantageous when the daily traffic in 2013-14 exceed 5,000 vehicles at level crossings with 2-lane roads, and 8,500 vehicles in the case of 4-lane roads.

These results are for the case when the number of trains on the DFC and the existing rails will increase from 80 trains per day per direction in 2013-14 to 230 in 2031-32. The results will differ in the section of the diversion route of the DFC, and the sections where the number of the existing tracks is large, and others.

(5) Relation with TVU

Indian Railways adopts TVU as a guideline for ROB construction, which is defined as:

$$TVU = \text{No. of Trains} \times \text{No. of Vehicles}$$

TVU does not account for the impact of closing time reduction by automatic level crossing control and other improvement methods, because the closing time per train is not incorporated into the definition. This project proposes the introduction of automatic level crossing control, and in this case, it would be proper to adopt a higher TVU than that is used by Indian Railways for the guideline of ROB construction.

It should be noted that when vehicles arrive at a constant rate, the loss of time is in proportion to "No. of train × square of (closing time per train)". Therefore, if closing time per train decreases to $1/x$ times, it is possible to increase the number of trains to x^2. Thus, it is rational for this project to adopt the adjusted TVU defined as:

Adjusted TVU = TVU × $(Ta/Tb)^2$
where, Ta = closing time per train at present
Tb = closing time per train after improvement

Applying Ta = 6 minutes and Tb = 2 minutes (suburban), it is proper to evaluate the TVU of Indian Railways after multiplying $3^2=9$ in case of automatic level crossing control. For TVU = 100,000 (criterion for ROB construction by Indian Railways), the adjusted TVU = 900,000 will be new criterion for this project.

On the other hand, for the proposed criteria where ROB construction becomes recommendable in terms of economic loss, the relevant TVUs worked out to be:

Suburban: 7,000 × 160 = 1,120,000 TVU (2013-14)
Urban area: 7,000 × 160 = 1,120,000 TVU (2013-14)

Assuming an annual growth rate of 5% for road traffic up to 2013-14, above adjusted TVUs are converted by $1/1.05^8 = 0.68$ as:

Suburban: 1,120,000 × 0.68 = 762,600 TVU
Urban area: 800,000 × 0.68 = 544,000 TVU

(6) Recommendation for selection of ROBs

The calculation includes a large number of assumptions to establish the standard criterion for typical level crossings. Usually, it is necessary to evaluate each level crossing individually based on the local condition. On the other hand, when the project scale is very large like on this project, it is practical to screen proposed level crossings for ROBs using rough criteria. Therefore, it is recommended that ROB locations be selected according to the following criterion based on the calculations in this section.

In principle, ROBs should be constructed at the level crossings where TVU in 2005-06 exceeds 900,000. Other than the above level crossings, a feasibility study for the construction of ROBs should be carried out for each level crossing to decide whether or not it should be constructed, if TVU in 2005-06 exceeds 500,000.

5.5.2 Study of level crossing systems

1) Proposal of automatic level crossing control system

Existing level crossings in Indian Railway is described in the *PET-II Report* as follow.

a) Level crossing warning staff is placed at each level crossing. There will be no unmanned level crossing.

b) Warning staff contacts the staff at nearby station with a communication device (for example, magneto telephone).

c) Receiving information on an approaching train, the warning staff closes the level crossing gate.

d) There are 3 types of level crossing gates: swing gates, lifting barriers and leaf gates.

Almost all gates are manually driven.

e) The condition of the closed level crossing gate is linked to the starting signal or automatic block signal near the level crossing, but there is no-linked to the signal.

2) For the purpose of train and road traffic safety, the following improvements are desirable.

a) All the level crossing for the DFC and existing lines parallel with DFC should be interlocked to the train signal.

b) If there is no train signal in the approach section, the level crossing signal for the train should be provided.

c) Gates should be automatically controlled with the motor, and the closing time should be optimized, which will also stop faulty operation by the staff.

(1) The philosophy of automatic control of level crossing

With the automatic control of level crossings, the following effects can be expected. The details of this system are shown in *Volume4 Technical Working Paper Task2, 5-(6) Study of Level Crossing Systems.*

When the level crossing is automatically controlled, warning staff will be still in place. This will have the advantage of:

a) Optimum warning times (reduce unnecessary long warning times).

b) Better work efficiency of warning staff (staff can dedicate more time and attention to road traffic control).

c) Faulty operation (gate left open although train is approaching the level crossing) by miscommunication will be prevented, especially for special trains.

The following additional effects may be expected if warning staff is also placed at level crossing in the conventional manner.

a) Speedy clearance of road side at the level crossing due to traffic control by the warning staff. (Train operator need not reduce the speed.)

b) Emergency operation by the warning staff.

c) Protect the level crossing against vandalism.

Refer to *Technical Working Paper* about the functions of the automatic level crossing control system.

CHAPTER 6
TRANSPORT PLANNING

CHAPTER 6 TRANSPORT PLANNING

6.1 PURPOSE OF THIS CHAPTER

In the previous section of this chapter, all the elements of transport, such as required number of rolling stock, were calculated.

Transport planning involves the clarification of many factors. One factor, travel time is calculated based on route alignment. This includes factors such as gradient and radius as well as the performance characteristics of the rolling stock. Next, headway is calculated. This is based on the number of trains found in the demand forecast. Transport planning is then implemented based on travel time, headway and train km, which is also obtained through the demand forecast. These calculations will result in the creation of the train diagram. The number of locomotives and wagons can be calculated based on the travel time and demand forecast. These figures will be utilized as the base data for the economic and financial evaluation.

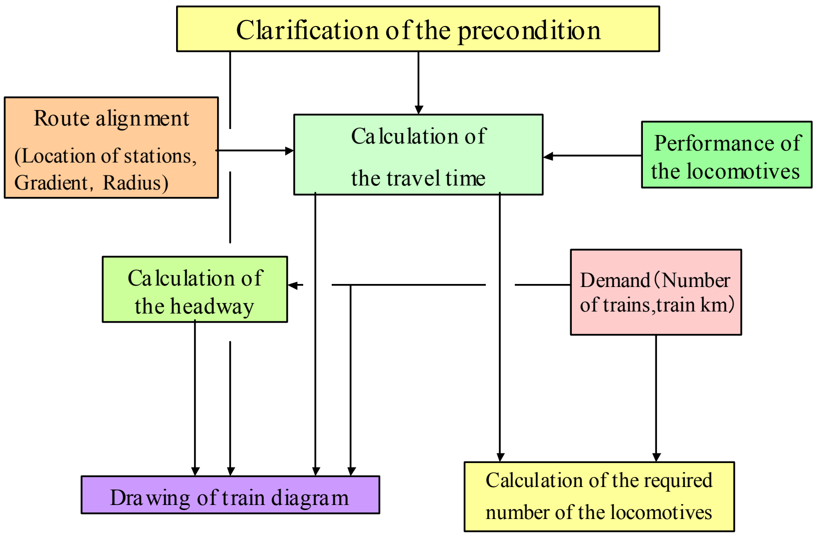


Figure 6-1 Flow Chart of the Transport Planning

In the latter section of this chapter, starting from 6.7, the transport measures to improve the quality of inter-modal transport to meet with the needs of customers will be discussed.

6.2 PRE-CONDITIONS OF TRANSPORT PLANNING

To be able to implement the train operation of 140 trains per direction per day, the preconditions shown in Table 6-1 are the assumptions used for transport planning in this report.

Table 6-1 Precondition of the Transport Planning

Items		General Specifications	Remarks
Rules		- General Rules and its subsidiary rules for DFC will be prepared according to the conditions shown below.	
Train		- Maximum speed of all trains is 100 km/h. - Brake van will not be connected to the rake. - The time required for the changing of the locomotives will be within 15 minutes, including the air-brake test. - Every train on the DFC will have a time table.	
Intermediate stations	Double track section	- Crossing stations will be provided every 30-40 km for treatment of rolling stock with mechanical /electrical failure and for detention at the time of disruption. Trains can pass other trains at these stations. - Junction stations will be provided for operational connection with conventional lines.	
	Single track section	- Most of the freight trains operated on the single track sections carry coal and are empty in one of the directions of travel. From an operational point of view, it would be preferable that the trains loaded with commodities can go through stations without reducing speed. where the freight trains with empty wagons are waiting - Interval of the crossing stations will be 10 km in general. It would be preferable that the distance between these stations be nearly equal for each section, as this would simplify arranging the net train operation plan.	
ICDs		- The cargo handling and the arrival/departure loop will be provided separately at terminals. The handling loops at the terminals will not be electrified.(At intermediate stations, the handling of containers can be safely carried out by using the disconnecting switch for overhead contact wire at the arrival/departure loop) - The time from arrival to departure will be less than or equal to 3.5 hours for single stack container (SSC) trains and less than or equal to 5.5 hours for double stack container (DSC) trains.	
Drivers		- The freight train will be operated by one man and will not have a guard and/or an assistant driver. - The time for crew change will be within two minutes.	
Locomotives		- Both locomotives for container trains (SSC: 3100 t, DSC:3500 t) and commodity trains (5800t) will have enough power to pass the 2000 m point from the departure position within 3.5 minutes on a level section. - The balanced speed at 5 ‰ gradient section will be more than 65 km/h.	Hauling 5800 t : Locomotive with 8 axle and 12,000HP Hauling 3500 t : Locomotive with 6 axle and 7, 200HP
Wagons		- Free running time at normal braking will be within 15 seconds at the maximum number of wagons. (Similar to at present in India) - The normal brake shall have the performance of 1.0 km per hour per second reduction in speed on a level section. (Similar to at present in India)	
Signals		- The length of signal block will be located at intervals of 1 km near stations and 1.5 km at the intermediate sections between the stations. The distance can also be reduced to less than the distance mentioned above.	Wayside signal
		- The operation control systems will be provided at the central control centre. The system for each corridor will be constituted separately and will also be equipped at the central control centre.	

Items	General Specifications	Remarks
Tracks	- The maximum gradient will be within 5‰. The minimum radius of horizontal curve will be 700m.	
	- The maximum speed at the diverted side of the turnouts on the route where trains may pass through will be more than 60 km/h. - The maximum speed at the diverted side of the turnouts on the loops where every train stops will be more than 45km/h.	One in sixteen One in twelve
	- The total number of loops on DFC will be more than the maximum number of trains remaining on the DFC simultaneously. This will give the ability to stable all the trains on the loops of stations in the event of a disruption. (Note: DFC will have less stations than the existing lines)	
	- Track maintenance time will be secured for 4 hours for each direction separately per day.	
Electrification	- The capacity of the power supply will be secured to ensure more than the power demand for the operation of 140 trains per direction per day. (Phased implementation according to the traffic demand would be preferable)	

Source; JICA STUDY TEAM

6.3 STAGE-WISE IMPLEMENTATION AND TRAIN-KM

In the demand forecast the data of the train-km is provided with that of the yearly demand forecast. (Bulk: ton-km, Container: TEU-km) Table 6-2 and Table 6-3 show the sections and yearly train-km data by stage of implementation.

Table 6-2 Section and Yearly Train-km by Stage (Eastern Corridor)

Fiscal year	Ludhiana－Khurja	Khurja-Mughal Sarai	Mughal Sarai -Sonnagar	Train km (Million)	
	The 1-b stage	The 1-a stage	The second stage	Bulk	Container
2013-14	-	○	-	18.6	0.4
2018-19	○	○	○	37.6	0.8
2023-24	○	○	○	39.3	1.0
2028-29	○	○	○	41.1	1.1
2033-34	○	○	○	42.0	1.2

Note; The section other than 1-a will be opened in 2015-16.
Source; JICA STUDY TEAM

Table 6-3 Section and Yearly Train-km by Stage (Western Corridor)

Fiscal year	Dadri－Rewari	Rewari-Vadodara	Vadodara-JNPT	Train km (Million)	
	The second stage	The first stage	The 1-b stage	Bulk	Container
2013-14	-	○	-	10.2	14.8
2018-19	○	○	○	15.3	45.3
2023-24	○	○	○	16.7	67.1
2028-29	○	○	○	18.2	88.2
2033-34	○	○	○	19.2	101.3

Note; The section other than 1-a will be opened in 2015-16.
Source; JICA STUDY TEAM

6.4 ESTIMATION OF TRAIN TRAVEL TIME

Most of India is flat and there are few small curves in the track. So Indian Railways has no need for strict and precise estimation of travel time and it does not calculate travel time between stations that reflects slowing down at the curves and gradients. This time estimation of the traveling was calculated based on the data of the performance of the rolling stock for DFC and the route alignment of the DFC which is proposed by JICA Study Team (JST).

6.4.1 Pre-conditions for the estimation of the travel time

(1) Route

The route alignment data (including the mileage between the starting and ending points of the gradients and curves) that was prepared by the JST is adopted for this calculation.

(2) Signals

The alignment of the signals is based on the route alignment designated on the previous assumption. The signals near stations are assumed to be located as shown in Figure 6-2.

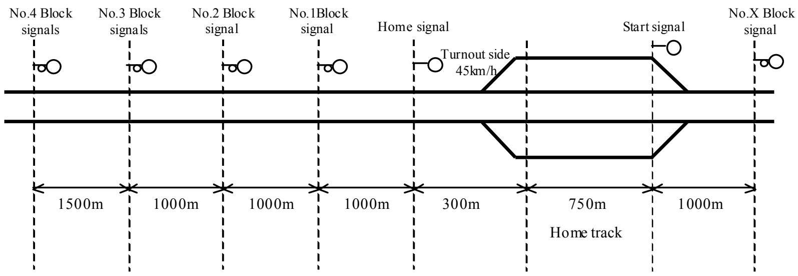


Figure 6-2 Signal Alignment Near Stations

(3) The performance of the locomotives

The performance of the locomotives was assumed to be shown at the Table 6-4.

Table 6-4 Performance of the Locomotives for DFC

Locomotives		For bulk trains	For container trains	
			DSC (Well-type)	SSC
Haulage tonnage		5,800 t	3,500 t	3,100 t
Number of axles		8	6	6
Tare weight		200 t	150 t	127.8 t
Power		12,000 HP	9,000 HP	6,000 HP
Maximum speed		100 km/h	100 km/h	100 km/h
Travel time to 2000 m from the starting point		Within 3.5minutes	Within 3.5minutes	Within 3.5minutes
Normal brake	Free running time	Lower than 15sec.	Lower than 15sec.	Lower than 15sec.
	Average deceleration speed	More than 1km/h/s	More than 1km/h/s	More than 1km/h/s

Source; JICA STUDY TEAM

(4) Miscellaneous operation times

Driver exchange will take place at the junction stations. So the stopping time at junction stations will be a minimum of two minutes.

6.4.2 Calculation of travel time

Travel time was estimated using train operating curves. The curve is shown in *Volume4 Technical Working Paper*. The travel times when a 12,000 HP locomotive hauls 58 wagons weighing 5,800 t among major stations is shown in Table 6-5 and Table 6-6. These are assumed to be typical travel times.

Table 6-5 Travel Time on the Eastern Corridor (12,000HP-58 wagons – 5800 t)

Staion	Location of station (km)	Section distance (km)	Travel time (h:mm:ss)	Stopping time (Minute)	Accumulated travel time (h:mm:ss)	Section average speed
Sonnagar	549					
Ghanj Khwaja	668	119	1:18:00	0:02:00	1:20:00	89.2
Mughal Sarai	676	8	0:09:00	0:02:00	1:31:00	43.6
Jeonathpur	684	8	0:08:45	0:02:00	1:41:45	44.7
Chheoki	812	128	1:23:45	0:02:00	3:07:30	89.3
Manauri	845	33	0:25:15	0:02:00	3:34:45	72.7
Prempur	997	153	1:39:15	0:02:00	5:16:00	90.4
Bhaupur	1,049	52	0:37:45	0:02:00	5:55:45	78.5
Dhaud Khan	1,333	283	3:01:15	0:02:00	8:59:00	92.7
Khurja	1,384	52	0:37:15	0:02:00	9:38:15	79.2
Kalanaur	1,615	231	2:28:30	0:02:00	12:08:45	92.1
Sirhind	1,700	85	0:57:30	0:02:00	13:08:15	85.7
Dhanmdari Kalan	1,725	25	0:19:30	0:02:00	13:29:45	69.8
Ludhiana	1,778	53	0:37:15	0:02:00	14:09:00	81.0
Total	1,789	1,240	13:53:45	0:26:00	14:19:45	86.5

Source; JICA Study Team

Table 6-6 Travel Time on the Western Corridor (12,000 HP-58 wagons – 5800 t)

Station	Location of station (km)	Section distance (km)	Travel time (h:mm:ss)	Stopping time (Minute)	Accumulated travel time (h:mm:ss)	Section average speed
JNPT	1					
Vasai Road	79	78	0:58:30	02:00	1:00:30	92.3
Gothangam	326	247	2:37:45	02:00	6:20:00	92.8
Makarpura	420	94	1:02:30	02:00	4:44:45	87.4
Sabarmati	560	140	1:31:15	02:00	7:51:15	90.1
Mahesana	611	51	0:36:15	02:00	6:56:15	80
Palanpur	703	92	1:02:30	02:00	8:00:45	85.8
Marwar	917	214	2:18:30	02:00	12:41:45	91.4
Phulera	1,139	222	2:28:00	02:00	15:21:15	88.7
Rewari	1,352	213	2:18:45	02:00	17:32:45	90.8
Dadri	1,465	112	1:14:15		16:26:15	90.9
Total	1,465	1,464	16:08:15	0:18:00	16:26:15	89.0

Source; JICA Study Team

1) The travel time shown in Table 6-5 and Table 6-6 are the figures calculated in a mechanical fashion, which means that spare time is not included. Loading/unloading at the intermediate stations would be included in real train operation planning. Therefore, when preparing a train diagram or estimating the number of rolling stock, 20 % spare time will be added to the accumulated travel time. The average speed including this precondition is shown in Table 6-9.

2) The average speed of freight trains on the existing lines at the present stage was calculated based on the data of CRIS (Centre for Railway Information System) (See Table 6-7).

The data used for the calculation was related to 2005-06. The data for three months from June to September was excluded due to the monsoon season. Any data that was incomplete was also excluded.

Table 6-7 Average Speed of Freight Trains

Type	Zone	Average speed (km/h)	Number of sample trains
Container	More than 1,000 km	28.1	1,563
	800km -1,000 km	15.5	138
	500km-800 km	17.5	196
	Less than 500 km	9.2	215
Bulk	More than 1,000km	19.8	3,107
	800km -1,000km	17.2	492
	500km-800 km	16.6	1,666
	Less than 500 km	26.2	4,718

Source: Centre for Railway Information Systems

3) Average speed of freight trains which will run through DFC after its opening was estimated based on observed data that was obtained at the survey conducted in the driver cabins of container trains and bulk trains (See Table 6-8). These speeds are higher than the average speed of freight trains at present. Even at the present time, these trains seem to have priority in operation.

The trains through DFC will also be operated by priority. Since the observed time does not include the stopping time at both end stations, the speed that is obtained by cutting off the first digit from the observed speed is adopted for the average speed of the trains through DFC on the feeder line.

Table 6-8 Observed Data of Container and Coal Trains

Train type	Container	Coal
Date	31 Jan 2007	30 May 2007
Outline of trains	WAG7 hauls 45 wagons (2,035t) Maximum speed: 100km/h	WAG7 hauls 58 wagons (4,729t) Maximum speed 75 km/h
Departure station	Vasai Road (12：23)	Gomoh (8：48)
Arrival station	Surat (16：07：30)	Gaya (12：42)
Travel time	3 hours 45 minutes	3 hours 54 minute
Distance	215.15km	169.49km
Average speed	57.5 km/h (The stopping time at both end stations is not included)	43.5 km/h (The stopping time at both end stations is not included)
Remarks	Maximum speed at level section was 88-90 km/h. On downhill sections it could attain 96 km/h.	

Source; JICA Study Team

Table 6-9 Average Speed of Trains

Sections	Bulk trains	Container trains
On DFC	70km/h	70km/h
On feeder lines (Present stage)	20km/h	30km/h
Through trains to DFC on Feeder lines (after opening of DFC)	40km/h	50km/h

Source; JICA Study Team

6.5 ARRANGEMENT OF THE TRAIN OPERATION PLAN

6.5.1 Assumptions for the arrangement of the train operation plan

The assumptions for the arrangement of the train operation plan, in addition to the pre-conditions shown in 6.2, are as follows.

1) The maximum speed of the train will be fixed at 2 % less than that indicated for the section.
2) When the number of trains on Western Corridor exceeds the line capacity (140 trains/direction with maintenance block), container trains will be operated in the same manner as the DSC trains (the capacity of a DSC train with well type wagon is 1.5 times larger than that of SSC).
3) The performance of the locomotives for bulk trains in this report was sufficient and the difference of performance between the locomotives used for bulk trains and those used for container trains is small. Since the maximum speed of each is 100 km/h and there are few station stops, they will have similar travel times and this will simplify the creation of the time table. In actual practice the time table for the freight trains will be arranged based on the travel time of the bulk freight trains.
4) There are no regulations in the General Rules of Indian Railways about speed restrictions at the curves. So the speed restriction at curves has been tentatively fixed as shown in Table 6-10 based on the *Volume 4 Technical Working Paper Task2, 5-(2)*.

Table 6-10 Speed Restriction at Curves

Radius		Speed restriction km/h		
In Degree	In meters	DSC on flat	DSC on well	SSC
2.5	699	85	95	
3.0	582	75	85	90
4.0	437	65	75	85
6.0	291	55	60	70

Source; JICA Study Team

5) As the steepest gradient is 5‰, there is no need for speed restriction along the downward slope.
6) When the succeeding train arrives at the same loop of the station just after the departure of the preceding train, the headways will become longer than when trains arrive/leave from/to different loops.

   The junction station and the crossing station have extra loops for each main line respectively so the succeeding train does not need to arrive at the same loop of the station just after the departure of the preceding train.

Therefore, the arrival of the succeeding train at the same loop with the preceding train will be planned only when there is some redundancy in train operation during the planning stage.

7) Other headways near stations are shown in Table 6-11. The figures are rounded to the nearest 15 seconds above.

Table 6-11 Headway Near Stations

Case	Headway (Second)
Time after the departure of the preceding train that the succeeding train leaves from the adjacent loop	210
Time after the arrival of the preceding train that the succeeding train arrives at the adjacent loop.	165
Time after the passing of the preceding train that the succeeding train leaves this station	135
Time after the passing of the preceding train that the succeeding train also passes the station.	150
Time after the entrance of the preceding train into the loop line completely that the succeeding train passes the main line.	105

8) There is no limitation to the transport time zone, except for the maintenance block. The train operation plan is composed with equally distributed intervals for a complete day. The interval for maintenance work is set at 4 hours, but it is not restricted to the day time zone.

9) The locomotive will be released from the train after the arrival at the destination terminal. The daily inspection for locomotive shall be carried out at the arriving depot.

6.5.2 Establishment of the train interval

Train interval will be decided based on the calculated number of trains for each section, which in turn is based on the traffic demand. The minimum train interval for the line can be determined by the number of the trains at the section where the maximum number of trains are required.

The shaded cells in Table 6-12 indicate the critical sections for deciding the train interval. There are some sections in the Western Corridor that will exceed the line capacity of 140 trains from fiscal year 2028-29 on.

The number of trains is calculated based on the pre-condition of equal interval operation, except for the 4 hours of maintenance work time. DSC train shall be operated at the sections where the number of the trains exceeds 140 train line capacity. So the number of the trains in such a section shall be fixed as 140. The result of the calculation is shown in Table 6-13.

The headway is calculated using the formula shown below. The result of the calculation is shown in Table 6-14.

Train headway (minute)

= 20 (hr) x 60 (min)/maximum train number per day per direction

Table 6-12 Number of Trains at Each Section by Year (Average for Both Directions)

Section		2013-14	2018-19	2023-19	2028-28	2033-34
Sonnagar Jn	Mughal Sarai Jn		82.25	86.6	90	91.7
Mughal Sarai Jn	Cheoki	56.4	73.35	77.45	81.3	83.4
Chheoki	Prempur	57.9	81.1	83.3	85.65	86.9
Prempur	Bhaupur	59.0	84.9	88.05	91.4	93.2
Bhaupur	Tundla	63.3	93.05	97.05	101.2	103.5
Tundla	Daud Khan	52.0	83.1	87.1	91.35	93.7
Daud Khan	Khurja Jn	49.2	79.95	83.6	87.3	89.4
Khurja Jn	Dadri		45.2	47.4	49.8	51.1
Khurja Jn	Kalanaur		30.1	31.5	33	33.7
Kalanaur	Rajpura Jn		26.35	27.9	29.6	30.6
Rajpura Jn	Shirhind2		25.35	27.85	30.15	31.3
Shirhind2	Ludhiana Jn		25.35	27.85	30.15	31.3
JNPT	Vasai Road Jn		43.85	59.75	72.75	79.8
Vasai Road Jn	Gothangam		61.25	78.7	93.5	101.6
Gothangam	Vadodara		65.9	83.8	99	107.4
Vadodara	Ahmedabad	31.5	60.65	77.55	91.95	99.9
Ahmedabad	Palanpur Jn	35.1	57.95	78.15	95.6	104.5
Palanpur Jn	Marwar Jn	52.2	83.15	116.3	151.15	174.1
Marwar Jn	Phulera Jn	52.3	82.85	115.6	150.25	173.1
Phulera Jn	Rewari Jn	43.7	75.2	108	142.65	165.6
Rewari Jn	Pirthala		26.8	39.9	53.3	62.1
Pirthala	Dadri		8.45	11.75	15.15	17.3
Pirthala	TKD		18.4	28.15	38.2	44.8

Source: JICA Study Team

Table 6-13 Calculation of the Detailed Number of DSC and SSC at Fiscal Years 2028 and 2033

	Items	2028	2033	Remarks
A	Number of trains from the demand forecast	151	174	Number of trains is calculated by SSC in demand forecast A=B+C
B	Breakdown of container trains	116	137	Ditto
C	Breakdown of bulk trains	35	37	
D	Number of DSC trains	22	68	B= 1.5D+E C = 140-（D+E） Assumes that wagons are well type. Well type wagons can carry 150% the load of normal wagons.
E	Number of SSC trains	83	35	
	Total	140	140	C+D+E Total number is fixed to 140

Source; JICA Study Team

Table 6-14 Headway of Trains

Unit : Minute

Section		2013	2018	2023	2028	2033
Sonnagar Jn	Dadri	18	15	12	10	10
Khurja Jn	Ludhiana Jn	—	30	30	30	30
JNPT	Dadri	20	14	10	8	8

Source; JICA Study Team

6.5.3 Composition of train master chart

The train master chart will be drawn and submitted based on above data. (See *Volume 4 Technical Working Paper Task2, 6*)

6.6 CALCULATION OF THE NUMBER OF LOCOMOTIVES

In the actual work of calculation of the number of locomotives, locomotive operation charts will be drawn and the number of locomotives will counted as per requirement. As the train interval is uniformly defined, as presented above, in this study the required number of locomotives is calculated from the amount of running time and turn-round time.

6.6.1 Pre-conditions of the locomotive operation

1) All the locomotives for DFC are assumed to be newly procured.
2) Regard with through operation between Feeder lines and DFC, Diesel locomotives will be changed to Electric locomotive at the junction station in case of the feeder line is not electrified. Electric locomotive can be operated on both lines in case of the feeder line is electrified. The later case requires same performance needed for both line.
3) The locomotives are assumed to be operated within the DFC line for the purpose of estimating the investment cost of the DFC project, although the actual locomotive operation may be extended to the feeder lines.
4) The train-kilometre per day is converted from the data of the yearly train-km of the demand forecast. (See Table 6-15) Considering the fluctuation of transport, a year is counted as 330 days.

Table 6-15 Train-km/day

Fiscal Year	Eastern Corridor		Western Corridor	
	Bulk Wagon	Container Wagon	Bulk Wagon	Container Wagon
2013-14	56,461	1,145	31,057	44,949
2018-19	113,824	2,492	46,334	137,172
2023-24	119,228	2,929	50,513	203,266
2028-29	124,476	3,333	55,260	267,340
2033-34	127,298	3,535	58,305	307,071

Source; JICA Study Team

5) The train speed in Table 6-9 (DFC) is adopted for setting the average speed of trains
6) In the Western Corridor, the number of trains will exceed the line capacity, i.e., 140 trains per direction, in fiscal year 2028-29, so some of the trains will be operated as DSC trains from that time. Two scenarios are prepared for this calculation.

[Scenario A]

In general, the trains shall be operated in the SSC configuration. DSC trains will be operated only when the number of trains exceeds the line capacity with SSC trains.

Considering the quality and frequency of transport, it is preferable to transport commodities with SSC. (See *Chapter 5.1*) So this scenario will be adopted for the procurement of rolling stock.

When the number of trains for DSC or SSC has to be calculated respectively, the calculation methods shown in Table 6-13 are used for doing this.

[Scenario B]

The existing train through to DFC will be operated with SSC and the other trains to be operated on DFC only will be operated with DSC (The ratio of this type is assumed to be 30 %.) (See

Table 6-16).

Accordingly, the trains from the ports in Gujarat are assumed to be the trains to be operated on DFC only.

The results here will be utilized in the calculation for the comparison of wagon types in combination with locomotive power as shown in *Chapter 5.1*. The number of DSC will increase when this scenario is adopted. The increase in DSC trains provides the advantage of lowering the per-train depreciation cost of facilities.

7) The locomotives are assumed to be 5,800 t hauling ones for bulk cargo and 3,100 t hauling ones for single stack freight train, respectively.
8) The percentage of spare rolling stock is assumed to be 10% in consideration of monthly inspections and spares for disruption or engine trouble.
9) The turn-around time of the locomotives at the destination terminal is assumed to be 8 hours including shunting and daily inspection time.

Table 6-16 Ratio of the DFC Through Trains from/to Existing Lines (2004-05)

Departure station		JNP	Gujarat	Total
Arrival station	On DFC section (A)	5,021	1,315	6,336
	Out of DFC (B)	1,774	622	2,396
	Total (C=A+B)	6,795	1,937	8,732
Ratio（B/C）		26	32	27

Source: JICA Study Team

6.6.2 Required number of locomotives

The number of locomotives derived from the above assumptions is shown in Table 6-18 (Scenario A) and Table 6-19 (Scenario B). They were calculated as follows.

It should be noted that nos. of locomotives for feeder lines are not include in this estimation

Number of rolling stock required = ((Train km per day (Table 6-15)/Average speed on DFC section (Table 6-7) + Number of trains on DFC section (Table 6-17 converted to daily number) x Turn-round time (8 hours))/24 hours x 110%

Table 6-17 Number of Trains per Year on DFC Section (Both directions)

Fiscal year		2013-14	2018-19	2023-24	2028-29	2033-34
Eastern Corridor	Bulk	19,174	36,261	38,784	41,082	42,358
	Container	776	1,800	2,153	2,467	2,630
Western Corridor	Bulk	7,496	10,712	11,550	12,497	13,101
	Container	16,840	39,486	61,133	83,512	98,119

Source; JICA Study Team

Table 6-18 Yearly Required Number of Rolling Stock (Scenario A)

Fiscal year	Eastern Corridor		Western Corridor			Total		
	Bulk	Container 6000 hp	Bulk	Container		Bulk	Container	
				6000 hp	9000 hp		6000hp	9000 hp
2013-14	80	2	37	49	0	117	51	0
2018-19	156	4	55	134	0	189	138	0
2023-24	165	5	59	202	0	224	207	0
2028-29	173	5	64	192	51	237	197	51
2033-34	178	6	68	79	154	246	85	154

Source; JICA Study Team

Table 6-19 Yearly Required Number of Rolling Stock (Scenario B)

Fiscal year	Eastern Corridor		Western Corridor			Total		
	Bulk	Container 6000 hp	Bulk	Container		Bulk	Container	
				6000 hp	9000 hp		6000 hp	9000 hp
2013-14	80	2	37	15	23	117	17	23
2018-19	156	4	55	41	63	189	45	63
2023-24	165	5	59	61	94	224	66	94
2028-29	173	5	64	84	129	237	89	129
2033-34	178	6	68	94	145	246	100	145

Source; JICA Study Team

When determining the procurement number of rolling stock, there is a need to consider that DSC operation will be required from fiscal year 2028-29 on. Therefore, 9,000 hp locomotives should be selected as they can haul both DSC and SSC. As is shown above, SSC trains can be hauled with 6,000 hp locomotives but unifying the type of locomotive will provide numerous benefits including a reduction of procurement cost, simplification of locomotive scheduling and availability of spare locomotives in the event of a disruption. The yearly procurement plan based on the precondition above mentioned is shown in Table 6-20.

Table 6-20 Yearly Procurement of Rolling Stock

Fiscal year	Eastern Corridor				Western Corridor			
	Bulk		Container		Bulk		Container	
	Procured	Accumulated	Procured	Accumulated	Procured	Accumulated	Procured	Accumulated
2011-12	8	8	2	2	2	2	8	8
2012-13	30	38		2		2	30	38
2013-14	42	80		2	35	37	11	49
2014-15	16	96	1	3	4	41	17	66
2015-16	15	111		3	4	45	17	83
2016-17	15	126	1	4	3	48	17	100
2017-18	15	141		4	4	52	17	117
2018-19	15	156		4	3	55	17	134
2019-20	2	158	1	5	1	56	14	148
2020-21	2	160		5	1	57	14	162
2021-22	2	162		5	1	58	13	175
2022-23	2	164		5		59	14	189
2023-24	1	165		5	1	59	13	202
2024-25	2	167		5	1	60	14	216
2025-26	2	169		5	1	61	13	229
2026-27	1	170		5	1	62	13	242
2027-28	2	172		5	1	63	4	246
2028-29	1	173		5	1	64		243
2029-30	1	174	1	6	1	65		242
2030-31	1	175		6	1	66		240
2031-32	1	176		6	1	67		238
2032-33	1	177		6	1	68		236
2033-34	1	178		6		68		233

Source; JICA Study Team

6.6.3 Required number of wagons

The number of wagons used on DFC is calculated in the same way as locomotives. The number of wagons in a train set is 58 for bulk freight trains and 45 for container trains. The result of calculation is shown in Table 6-21.

Keep in mind that wagons that are used for the existing lines can be used on the DFC line also. So 70% of the required wagons on DFC are assumed to be converted from the existing lines. These wagons will be replaced yearly with new ones at a certain ratio per year according to their expiration of service date. For details, please see *Chapter 12*.

Table 6-21 Required Number of Wagons

Fiscal year	Eastern Corridor		Western Corridor			Total		
	Bulk	Container (SSC)	Bulk	Container		Bulk	Container	
				SSC	DSC		SSC	DSC
2013-14	4,640	90	2,146	2,205		6,786	2,295	
2018-19	9,048	180	3,190	6,030		12,238	6,210	
2023-24	9,570	225	3,422	9,090		12,992	9,315	
2028-29	10,034	225	3,712	8,640	1,836	13,746	8,865	1,836
2033-34	10,324	270	3,944	3,555	5,544	14,268	3,825	5,544

Source: JICA Study Team

6.7 INTRODUCTION OF WORKING TIME TABLE FOR FREIGHT TRAINS

6.7.1 Significance of introduction of working time table

IR does not prepare time tables for freight trains. On the DFC a time table will be indispensable as computerized traffic control system is planned to be introduced. From the view point of the improvement of inter-modal transport, the introduction of time table for through trains to DFC on the existing line is also indispensable.

Significance of introduction of time table is as follows.

(1) Implementation of computerized traffic control

Computerized traffic control system is planned to be introduced on the DFC. As the time table is to be the trigger data for the computerized system, introduction of time table is essential for this system.

(2) Enhancement of customer satisfaction

A lack of punctuality that is pointed out in *Chapter 9 of Volume 2 Task 0&1* is a major barrier to establishing inter-modal transport using rail. This is a fatal problem in terms of modern logistics and must be overcome. Hence, the introduction of a time table and a reservation system for containers based on that time table is absolutely essential.

Most of DFC trains will be from the feeder line sections. To improve the quality of the inter-modal transport, a time table for freight trains will be introduced not only for the DFC but also for the existing lines of IR.

(3) Implementation of high density operation

The introduction of time table is an indispensable measure for enhancement of the line capacity.

The line capacity will not be enhanced by the time table itself, but it will be indispensable as a management tool for high-density train operation. The number of trains that can be operated in a day is fixed and if some of those trains arrive late, the route secured for them will be wasted and the total number of trains that can be operated in that day will be reduced. A time table enables timely operation to be carried out.

(4) Efficient scheduling of locomotives

The current locomotive scheduling system for freight trains of IR has been arranged on the precondition that there is no time table and in some aspects, the absence of a time table has efficient features. However, in most cases, more efficient scheduling can be planned if there is a time table available. (See Figure 6-3)

One analogy can be seen in the preconditions for trains from feeder lines to DFC at junction stations in *PET-II of RITES*. It establishes the rule that trains requiring more than two locomotive changes for running on the DFC should not be operated on it. Their intention to reduce the coupling/uncoupling time for changing locomotives can be understood. But the DFC is electrified and the speed of trains will be much higher than that on the existing lines that are not electrified. The time lost in the changing of locomotives can be compensated by travel speed.

Perhaps there is some anxiety about the major time loss that will be brought about from the division of the locomotive schedule. With introduction of time table, their anxiety can be eliminated as the locomotive scheduling can efficiently be conducted with time table.

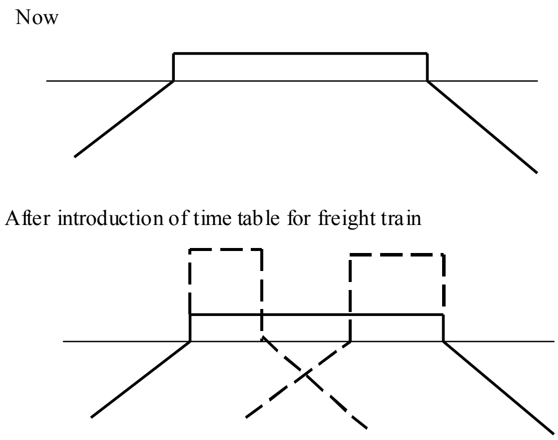


Figure 6-3 Efficient Scheduling of Locomotives with Time Table

(5) Efficient scheduling of drivers

As for the driver scheduling, IR has arranged a system that is compatible with the freight train operation without time table. As the drivers get higher allowance than other employees, they are proud of their work. But this system compels them to work on short notice without a schedule. With a time table for freight trains, they could be announced their work schedule a month or a week in advance.

6.7.2 Addressing the anxiety about the introduction of a working time table

MOR is anxious about the introduction of time table because they feel there is a lot of uncertainty in the freight train operations on the existing lines of IR and therefore the freight trains would not be able to keep their time table. The following lists some common reasons why a time table cannot be used and responds to them. It includes some experiences and ideas from Japan that can serve as a reference and may help to alleviate some of the anxiety.

1) *A time table cannot be used because there are a lot of problems, failures and passenger interference. There is a lot of passenger interference, such as mischievous tricks by passengers.*

The introduction of a time table for freight trains in itself will not cause an increase in the number of problems, failures or passenger interference. In fact, it will help to identify the steps that can be taken to decrease them.

The use of a time table for freight trains will make it necessary to clarify why a particular freight train was delayed. Reducing these troubles and failures will contribute greatly to improving the quality of the inter-modal transport. Frankly stated, it is better to identify the problems and correct them by using a time table than it is to try to conceal them by not using one.

Currently, freight trains frequently have to be stabled at intermediate stations for a long time because more trains are being assigned to operation than the available line capacity. When time table for freight trains is prepared, these long stabling time at stations may be fixed as a stopping time on the time table. At the present time, this stabling time could be considered a waste. But if this stabling time were regulated as inevitable with the present facilities or rolling stock, it could be fixed as a stopping time.

2) *A time table cannot be introduced because the load handling is done manually and cannot be accurately scheduled.*

During its site survey, JST heard that the handling of the commodities on the trains was done by hand. Moreover, it was learned that because of the wage structure, workers will stop their works after eight hours work even though their work is not complete.

Another report says that the entrance of the wagons is too narrow for a forklift to enter and the introduction of such equipment cannot be implemented immediately. This can be solved with a modification of the wagon structure that would enable the wagons to accommodate material handling equipment. A careful look at the current handling of materials would reveal methods for improvement.

Most of the load handling problems can be solved without difficulty.

3) *The destination of freight trains varies daily so that it's difficult to prepare a time table for an entire train.*

The destination of freight trains varies daily, but there is no need to prepare a time table daily. The time table will be prepared in coordination with the time table for passenger trains when the renewal of facilities or rolling stock or a change of the transport plan is carried out. As for the daily train operation, this is done mainly by editing the existing time tables. It will not be necessary to prepare a brand new time table for daily freight train operation (Figure 6-4).

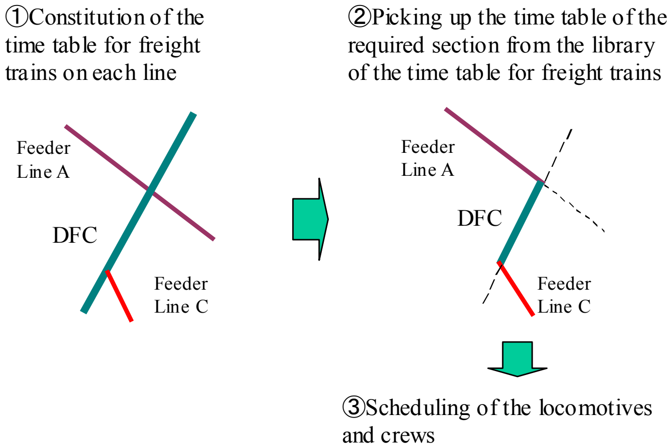


Figure 6-4 Time Table and Editing Work for Daily Freight Train Operation.

6.7.3 Step-wise introduction of working time table for freight trains on the existing lines (Proposal)

IR already has a working time table for the express container trains, which it calls "crack trains". This is just the arrangement between Zonal Railways and is not conducted by MOR. Moreover, this time table is prepared for internal use and not to be announced publicly. A working time table on the existing line can be realized by expanding the targeted lines and the number of trains to be targeted.

A temporary target could be the preparation of the working time table for the freight trains that run through to the DFC. It will not be necessary to introduce a time table for freight trains simultaneously over all the lines of IR. During the six-year construction period of DFC, the target lines and the trains can be increased step by step gradually. (See Figure 6-5). The introduction of the time table can then be publicly announced with the opening of the DFC.

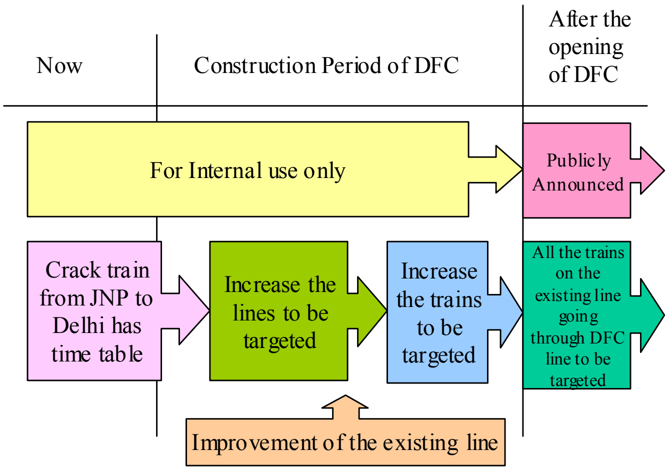
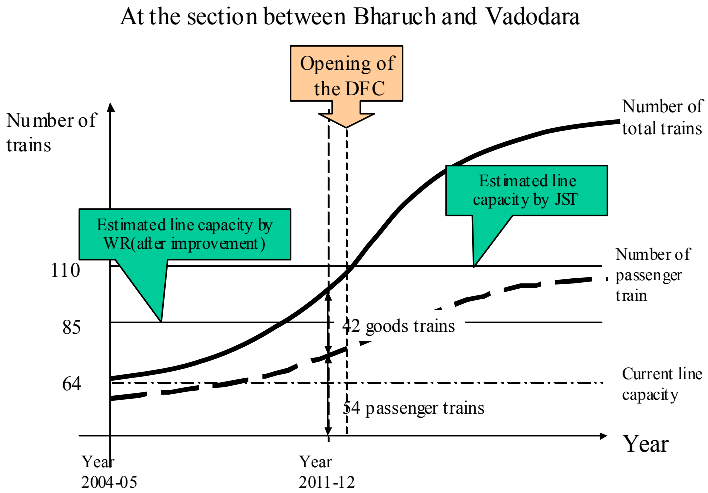


Figure 6-5 Step-wise Introduction of the Working Time Table for Freight Trains on the Existing Lines

6.8 MEASURES FOR INCREASE OF LINE CAPACITY

On the section between Bharuch and Vadodara in the Western Corridor, the traffic is estimated to be 96 trains per direction in fiscal year 2011-12, two years before the opening of the DFC. (See Figure 6-6) This figure already exceeds the line capacity for the double track sections with automatic signal of IR (85 trains without a maintenance block).

The time has come for the double track section of the existing line to enhance its line capacity by combining new measures with conventional measures.



Source; JICA Study Team

Figure 6-6 Necessity of Enhancement Line Capacity Before Opening of DFC

6.8.1 Various measures for increase of line capacity

Generally speaking, the introduction of an automatic signal system is often designated as a measure for increasing of line capacity. The line capacity is the total output of each facility that constitutes the railway system.

Table 6-22 shows various measures for increasing of line capacity. The colored areas in this table are the measures that IR has already implemented and most of them are now under construction or in the planning stage. It can be seen that not only has IR already introduced automatic signals, but it has also implemented most of the other measures for increasing line capacity. Supplementary information about the measures for increasing of line capacity is expressed below.

Table 6-22 Various Measures for Increasing Line Capacity

Issues to be improved	Status	
Automatic signaling	On going Some sections completed	Ahemdabad-Vasai Road
Improvement of the route alignment to avoid the route conflict	One going	Sanctioned for Vadodara st.
Enhancement of the speed restriction at the diversion side of the turnout	On going	Vadodara div.
Introduction of EMU with high acceleration and deceleration	Already introduced	At many sections
Introduction of the locomotives with high performance	On going	PPP project
Enhancement of the power supply	None	

Source; JICA Study Team

6.8.2 Abolition of the route conflict between up and down lines

When JST members rode in the cabin of a down locomotive for a container train operating between Vasai Road and Vadodara, it was repeatedly stopped due to route conflicts with up trains. This happened near big stations; the train ran smoothly in other sections. The upper part of Figure 6-7 shows that at the moment that the down train with JST members on board is leaving the Vasai Road and crossing over the up line to go to the down main line, the up train was stopped outside of the home signal. Such route conflicts were less distinct when an absolute block system (ABS) was used, but it seems that with the introduction of automatic signals, such phenomena became more evident. The route conflict at big stations is the biggest bottle neck after introduction of automatic signal.

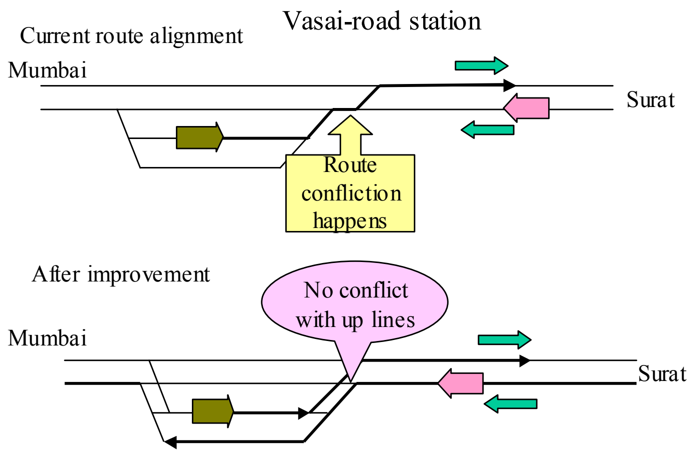


Figure 6-7 Route Conflict at Vasai Road Station

IR has already sanctioned an improvement project for abolishing the route conflict at Vadodara Station. In this project, the speed restrictions, (i.e., 15 km/h or 30 km/h), at the diverted side of the turnout will also be enhanced to 45 km/h by replacing the existing turnouts with new ones. The total budget for this improvement project is said to be Rs.150 million.

While line capacity is more or less determined by the capacity at bottle necks, the line capacity of a line will not increase as soon as the route conflict at a station is resolved. There are not so many stations that have route conflicts with up and down lines. Though the construction of the fly over would be expensive, the cost related to abolishing the route conflict will not be as big as was seen for the Vadodara station. So improvement of all the station yards along the line that have a route conflict with up and down trains will be proposed.

In addition, there may be cases in which the renovation of a station is planned, but the availability of land near that station was so limited that realizing the renovation plan is difficult. In such cases, it would be best to adopt a policy of relocating the facilities in the station yard to other stations. In this way, thanks to this project, a better plan can be established and the old facilities that have not chance for renewal can be reconstructed.

6.8.3 Enhancement of quality of facilities/rolling stock

In Japan, the track gauge is narrow (1,067mm), but the speed restriction at the diversion side of the 1 in 12 turnout is 45 km/h. In India, the track gauge is wide, but the speed restriction of the turnout of 1 in 12 is almost 15 km/h. This seems to be due to the structure of the turnout itself.

Locomotives with an “official” maximum speed of 100 km/h cannot attain their maximum speed on the level sections. This would indicate that there are some problems in the quality of the locomotives. (See Table 6-8)

In the discussion of the line capacity, the MOR side showed concern that because there are so many troubles or failures, freight train operation will fall into disorder when the time table is introduced. This also seems to be the problems of quality.

To renew all the facilities or rolling stock all at once seems to be an overwhelming task. Therefore, making the right choices when facilities or rolling stock have to be replaced becomes very important. Always replace them with ones with better quality or design.

6.8.4 Intangible measures

There are also intangible measures that can be used for increasing line capacity. An intangible measure requires the staff to essentially change their attitude and frame of mind towards a problem or their work. While implementing intangible measures can be difficult work, there is basically no expense for doing so. (See Figure 6-8).

The following is an example of an intangible measure. It was obtained from the site survey that was investigating increasing line capacity.

There is no speed restriction on the straight side of turnout. But in reality, a uniform speed restriction is regulated in the station yard. In the yard at Vadodara station, this speed is 15 km/h. And drivers feel that because there are many employees working on the cement covered area, it would be dangerous to pass through at a higher speed. There are also many passengers waiting for trains on the platform and passing through at a high speed would be also dangerous to these passengers. Therefore, even if the turnout were upgraded, the trains would still pass through the station at a slow speed because of this mind set of the administration staff and locomotive drivers. In other words, there would be no speed improvement through a station even if the turnout was upgraded.

It is relatively easy and inexpensive to provide warnings to the workers and passengers that a train will be passing through. Their safety can be ensured. The important task is to first have the will to enhance the speed restriction at the straight side of turnout for the trains on the main line and then address these human factors.

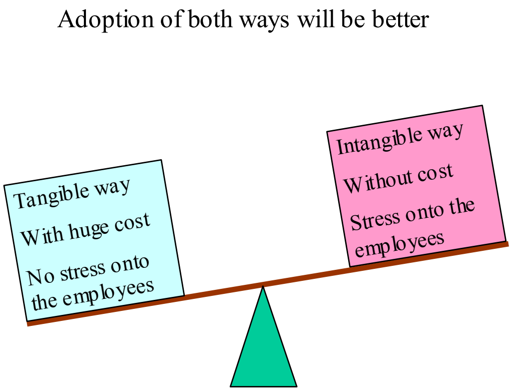


Figure 6-8 Tangible and Intangible Measures

Intangible measures have another feature – once an intangible measure is identified as good by the staff, implementing that measure becomes much easier. Therefore it is important to implement new intangible measures to the project as soon as possible.

As the figure shows, there is a need for a balance of tangible measures and intangible measures. However, once they are in balance, they become a big set of wheels that helps to move the project forward and attain dramatic results.

6.9 SMOOTH THROUGH OPERATION BETWEEN DFC AND EXISTING LINES

Major issue for the improvement of the quality of inter-modal transport is the connection between rail and ocean or road. The railway connection between DFC and existing lines faces some troublesome issues, such as reducing the amount of time required or minimizing the complexity of some of the shunting operations.

At the junction station, the following operations and activities must be performed like changing of locomotives and their drivers, waiting for a path, and the coupling/uncoupling of the brake vans.

All these operations have the potential for inducing a transport bottle neck. The following information and ideas are aimed at tackling these issues.

(1) Minimizing the time required for changing locomotives or drivers

At present, these operations place a heavy burden on the scheduling of locomotives and/or drivers. Crews in India travel a much farther distance than crews in Japan. It appears that the primary reasons for doing this are to reduce the time loss caused by crew changes and to avoid the troublesome work of crew scheduling.

When attempting to solve problems such as these, it is important to first analyze the contents of the work. As is explained in 6.7.1, an effective way to do this is to introduce time table for freight train going through to DFC. With enhancement of performance of locomotives and rationalization of the work sequence, the changing time of locomotives can be reduced to 15 minutes and crew changing time can be reduced to 2 minutes respectively. (See Table 6-23)

Table 6-23 Breakdown of Operations in Changing Locomotives by JR Freight

(Unit: Minutes)

Operation	Kita Kyushu Freight Terminal	Aomori signal station
Disconnecting of brake hose	2	2
Uncoupling of arrival locomotive	2	3
Coupling of locomotive	2	3
Brake test	2+5 (in case there is uncoupling/coupling works of wagons)	1
Total	8-13	9

Source; JICA Study Team

(2) Minimizing the waiting time for a path

When the freight train from the existing line goes through to DFC, this train will frequently have to wait for path at a junction station as this train will cut into the interval between DFC trains. Consequently there will be some possibility that the travel time of the train from the existing line will be extended.

When a train is entering an existing line from the DFC, this train will have to wait for the passenger train on the existing line to pass at junction station.

The introduction of time table for freight train seems to be one of the major measures for minimizing these waiting times. A time table will be a stepping stone for first managing and then minimizing this waiting time. Comprehensive traffic control by the central operation centre of the movement between the DFC and existing lines will also be an effective measure for minimizing of waiting time. (See *Chapter 9*)

(3) Eliminating the coupling/uncoupling of the brake van

These operations can be eliminated by not connecting the brake van. In this case the role of guard on the brake van would be taken over by an assistant driver. (See *Chapter9*)

6.10 HANDLING OF CONTAINERS AT ARRIVAL/DEPARTURE LOOP OF INTERMEDEIATE STATION

Currently, IR uses a train system that transports commodities by unit train directly from origin to destination. This system was introduced at a time when there was a transport crisis caused by the demand for transport exceeding the transport capacity. With this unit-train system, commodities from stations with small volumes to transport remain at the station until there are enough commodities to make a full train.

In the study of the improvement of the quality of the inter-modal transport, it was pointed out that containers between stations with low transport volumes are often stabled for a long time at the origin station. Obviously, such a practice increases the total number of travel days for these containers. In order to enhance the train frequency at intermediate stations without reducing the load per train, the container trains will have to handle cargo whose destinations are different. This means that containers will have to be handled at the intermediate station. However, if such shunting is carried out for handling of containers, it will cause longer travel time between the origin and destination. So in Japan, the loading/unloading of containers is carried out at the arrival/departure loops. Such high-level handling works should be introduced to enable full utilization of the DFC. For reference, in Japan, one stop increases the travel time by 20 to 40 minutes. The loading/unloading of a container requires only one minute.

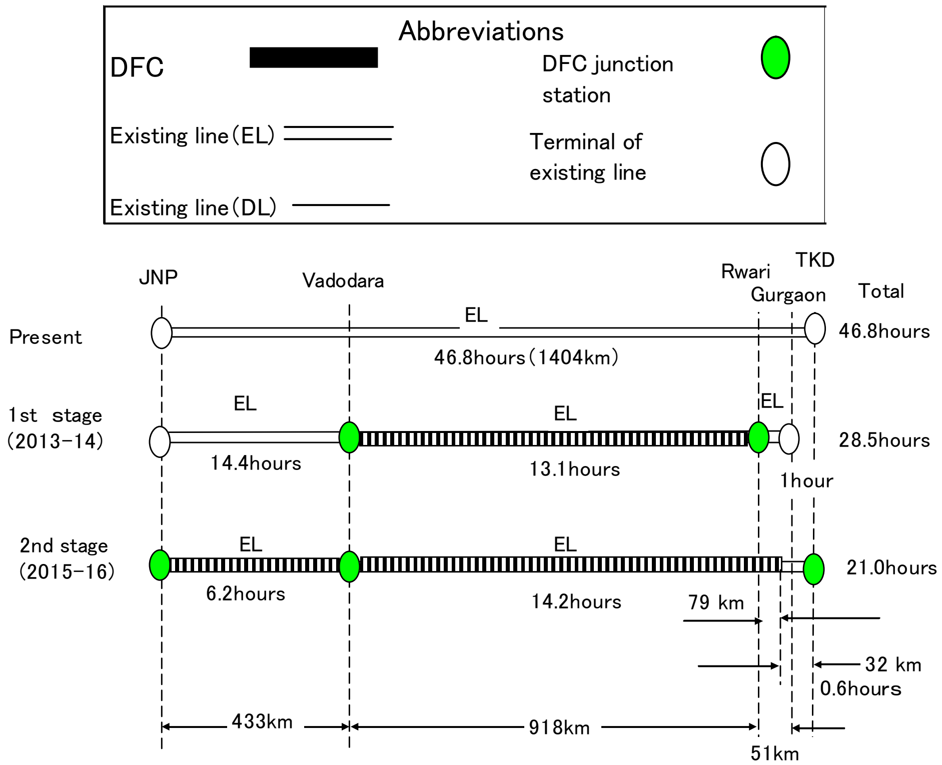
The following should be prepared for performing container handling at the arrival/departure loops at intermediate stations.

- A time table should be introduced to enable the circumstances in which precise scheduling can be implemented.
- Punctual train operation should be maintained. This enables the work to be carried out according to precise scheduling.
- DFC is planned to be electrified with 25 kv AC. Certain steps should be taken to ensure safety and facilitate container handling at the arrival/ departure loops. These include providing a disconnect switch for the overhead contact wire and a lift limiter on the forklifts to prevent the lifted consignment from being extended beyond a preset safe height.

6.11 TRAVEL TIME BETWEEN MAJOR STATIONS

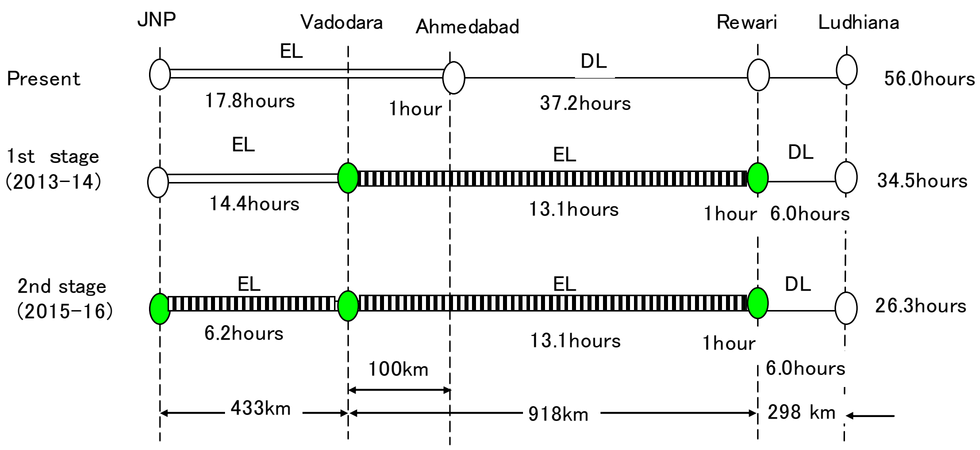
The travel time between the major DFC stations was calculated for each stage of DFC development. These sections include feeder lines. (See Figure 6-9 to Figure 6-9) The travel time is reduced in each stage. The reduced time is smaller than that which could be obtained with the improvement of the quality of inter-modal transport. (See *Chapter 8*)

This calculation uses the figures for the train speeds found in Table 6-9. The changing time of locomotives is 15 minute according to Table 6-1, but an hour is assigned here to provide an extra margin of time.



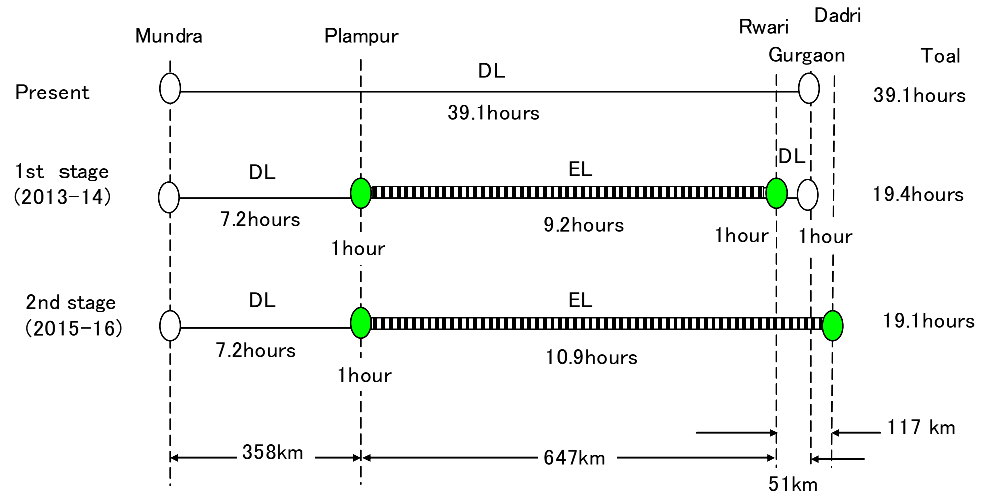
Source; JICA Study Team

Figure 6-9 Travel Hours by Stage (JNP-TKD)



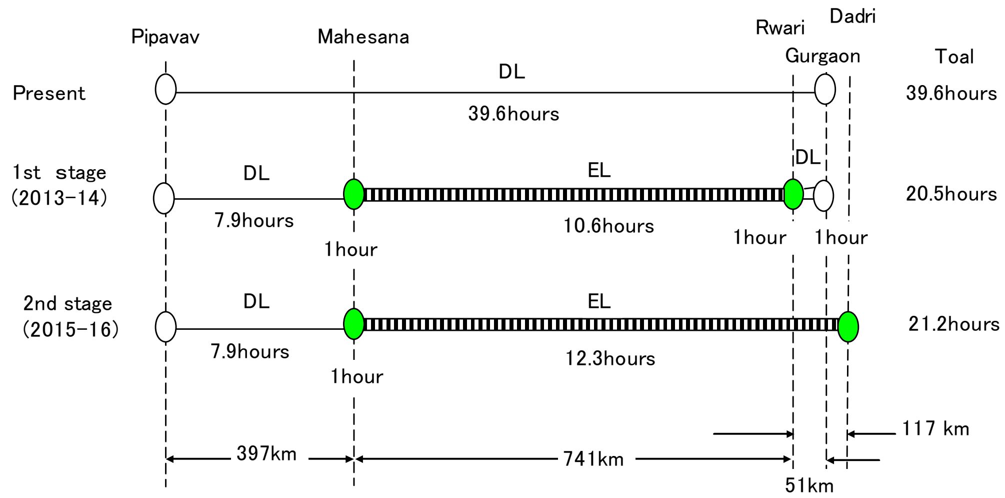
Source; JICA Study Team

Figure 6-10 Travel Hours by Stage (JNP-Ludhiana)



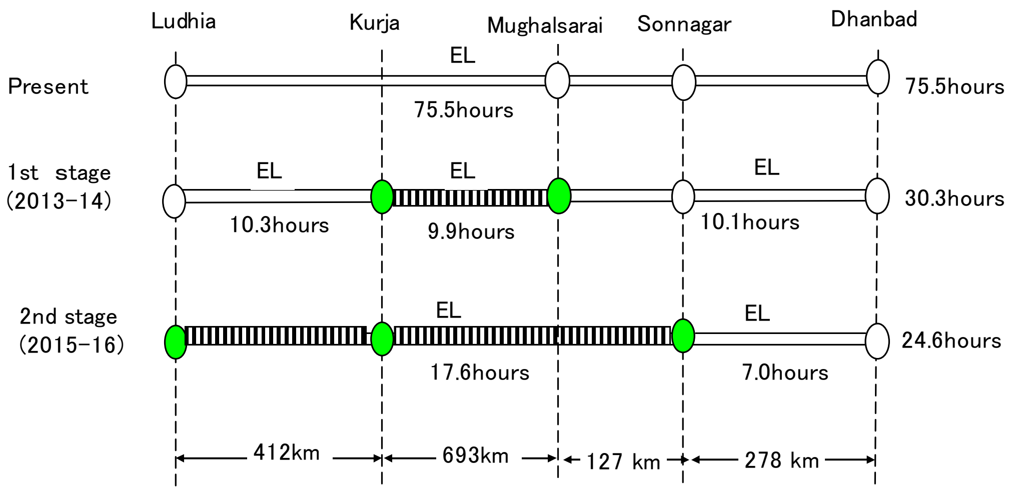
Source; JICA Study Team

Figure 6-11 Travel Hours by Stage (Mndra- Gurgaon/Dadri)



Source; JICA Study Team

Figure 6-12 Travel Hours by Stage (Pipavav-Gurgaon/Dadri)



Source; JICA Study Team

Figure 6-13 Travel Hour by Stage (Dhanbad-Ludhiana)