CHAPTER 6
DEMAND FORECAST

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6.1 INTRODUCTION

(1) Demand Forecast of Task-1

In this study, the demand forecast work consists of two components: 1) Justification of the DFC (***Task-1***) and 2) Feasibility Study for the DFC (***Task-2***). Demand forecast in ***Task-1*** aims to provide sufficient projection for the alternative analysis in order to justify the DFC.

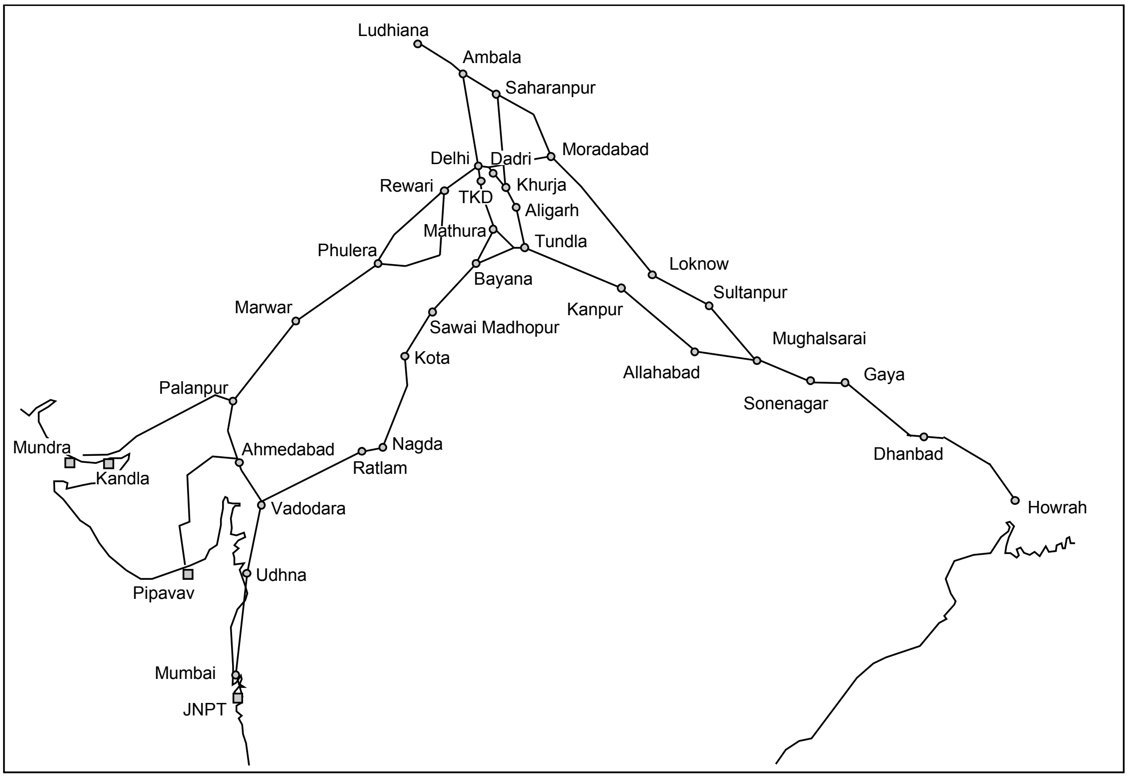
The JICA Study Team has carried out demand forecast up to 2031-32, for not only the DFC but also overall rail based traffic with passenger transport along the Corridors. The projection was used for capacity-demand analysis of alternative studies and preliminary economic and financial analysis. There were some differences between the two projections, but the results are very similar.

(2) Contents of Demand Forecast in Task-1

The demand forecast in Task-1 consists of:

1) Socioeconomic Framework,
2) Freight Demand Forecast,
3) Passenger Demand Forecast,
4) Corridor Traffic, and
5) DFC Traffic

Figure below illustrates a reference map for this Chapter.



Source: JICA Study Team

Figure 6-1 Reference Map of Chapter 5

6.2 SOCIO-ECONOMIC FRAMEWORK

6.2.1 Population

Currently, Indian population is estimated to be 1,109.9 million according to the website of National Commission on Population, India (as of February 2007). The Office of the Registrar General & Census Commissioner, India, projected the future population from 2001 to 2026 in India and States based on the Census of India 2001 (Table 6-1). Indian's population would be about 1.4 billion in 2026 according to the projection. The annual increase rate is estimated to decrease gradually from 1.6% to 0.8% during 2001 – 2026. The compound annual growth rate (CAGR) of the projected population in India from 2001 to 2026 works out to be 1.2%. On the other hand, the United Nations has a population projection for India up to 2050. The former projection was used for the future population up to year 2026, while the latter was used afterward for population projections in this Study. The proportions of a state in year 2026 were applied to the projections of state-wise population after the year 2026.

Table 6-1 Population Projection of India

(million)

2001	2006	2011	2016	2021	2026
1,029	1,112	1,193	1,269	1,340	1,400

Source: Report of the Technical Group on Population Projections Constituted by the National Commission on Population, May 2006

6.2.2 Economic Growth

In the 10th National Economic and Social Development Plan (NESDP), the target GDP growth rate was set at 7.93% for 2002-2007. The actual growth rate in the 10th Five Year Plan is likely to be 7%, lower than the target growth rate. Considering the recent economic growth in India, in the next five years India would achieve higher economic growth rate. The recent growth rates were 7.4% in 2004-05, 9.0% in 2005-06 and 9.2 % in 2006-07. At this moment, an annual growth rate of 8.5% is regard to be the most rational target growth rate of Indian economy for the 11th Five Year Plan[1]. ADB projects 8.0 – 8.5% annual growth rate from year 2008 to 2012 according to Asian Development Outlook 2006. International Energy Agency assumes a lower growth rate at 5.6% for long term in World Energy Outlook 2004.

In traffic demand forecast, this study applies a GDP growth rate of 7% per year for all the project period. Note that if GDP grows at an annual growth rate of 7% for 25 years, GDP in 2031-32 will reach 5.43 times that of 2006-07.

[1] Toward Faster and More Inclusive Growth, An Approach of the 11th Five Year Plan, Planning Commission

6.2.3 Industrial Structure

The proportions of primary, secondary, and tertiary sector to GDP were 20.5, 21.9, and 57.9% in 2004-05. Considering the development trends of other developed and developing countries, it was assumed that the proportions would become 5, 20, and 75% in 2050-51 as follows:

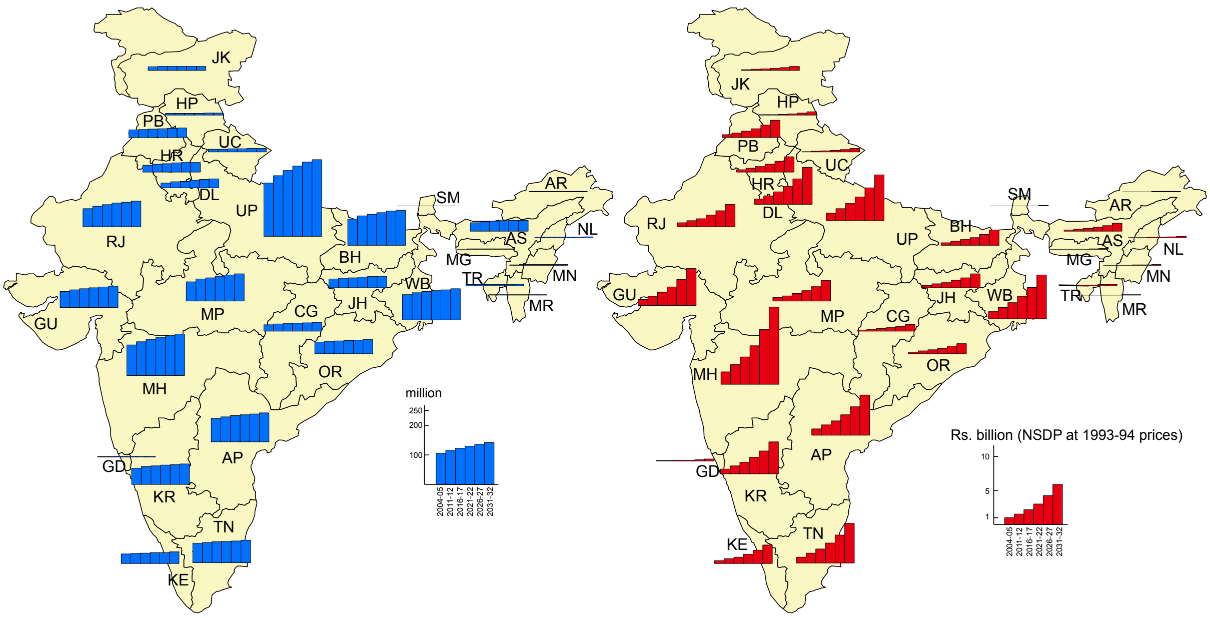
	Primary Sector	Secondary Sector	Tertiary Sector
2004	20.5%	21.9%	57.6%
2050	5%	20%	75%

For the intermediate years, a sector-wise proportion of GDP was interpolated linearly between the year 2004-05 and 2050-51. State-wise Net Domestic Production was calculated based on the proportion of Net State Domestic Product (NSDP) to Net Domestic Product (NDP) as follows:

$$P_{ai}(t) = P_{ai}(t-1) + \{P(t) - P(t-1)\} \times R_a(t) \times p_{ai}$$

where, $P_{ai}(t)$ = Production of sector a of state i in the year t
$P(t)$ = Production of India in the year t
$R_a(t)$ = Proportion of sector a to the total production in the year t
p_{ai} = Proportion of state i to all India for sector a in the year 2004

Table 6-2(next page) shows the macro- economic framework applied in this Study, and Figure 6-2 illustrates state-wise population and NSDP.



Source: JICA Study Team

Figure 6-2 Population and NSDP Growth by State

Table 6-2 State-wise Socioeconomic Framework

No.	State Name	Population (Lakh)						GDP (Rs. Billion), at 1993-94 prices						GDP of Secondary Sector (Rs. Billion)					
		2005-06	2010-11	2015-16	2020-21	2025-26	2030-31	2005-06	2010-11	2015-16	2020-21	2025-26	2030-31	2005-06	2010-11	2015-16	2020-21	2025-26	2030-31
1	JAMMU & KASHMIR	110	118	125	130	135	140	99	139	194	271	377	525	11	15	21	30	41	57
2	HIMACHAL PRADES	65	68	71	74	76	79	91	127	178	249	348	487	30	42	59	82	113	157
3	PUNJAB	262	278	292	304	314	326	468	652	906	1,255	1,735	2,395	101	141	197	273	378	523
4	CHANDIGARH	11	15	18	23	25	26	36	51	73	105	150	215	9	13	18	25	34	47
5	UTTAR PRADESH	1,844	2,019	2,192	2,357	2,496	2,594	1,225	1,710	2,379	3,304	4,581	6,344	237	331	461	639	886	1,226
6	HARYANA	235	256	276	295	312	324	392	548	766	1,069	1,491	2,078	98	137	191	265	367	509
7	DELHI	162	186	215	247	282	293	845	1,198	1,710	2,450	3,521	5,068	158	220	306	425	589	815
8	RAJASTHAN	627	682	733	780	817	849	567	794	1,113	1,558	2,183	3,056	151	211	294	408	565	782
9	UTTRANCHAL	93	100	107	113	118	122	93	130	182	253	352	489	21	30	41	57	79	109
10	BIHAR	913	982	1,043	1,098	1,141	1,186	411	573	796	1,101	1,521	2,097	29	40	55	77	106	147
11	SIKKIM	6	6	6	7	7	7	8	11	15	21	30	42	2	3	4	5	7	10
12	ARUNACHAL PRADE	12	12	13	14	14	15	12	17	24	34	47	65	2	3	5	6	9	12
13	NAGALAND	21	23	24	25	26	27	32	45	63	88	123	171	3	5	7	9	13	18
14	MANIPUR	23	25	26	27	28	30	23	33	46	64	89	125	5	7	10	14	19	26
15	MIZORAM	10	10	11	11	12	12	12	17	24	34	48	69	2	3	4	5	7	10
16	TRIPURA	34	36	38	40	42	44	40	56	78	110	154	216	8	11	16	22	31	42
17	MEGHALAYA	25	26	28	29	30	32	30	42	58	81	114	159	4	6	8	12	16	22
18	ASSAM	288	307	326	343	357	371	209	292	407	564	782	1,082	25	34	48	66	92	127
19	WEST BENGAL	853	898	938	976	1,007	1,047	1,100	1,543	2,164	3,035	4,257	5,972	216	302	420	582	807	1,117
20	JHARKHAND	295	316	338	358	375	389	377	525	727	1,004	1,384	1,904	108	150	209	290	402	556
21	ORISSA	390	409	426	442	454	472	260	363	506	704	978	1,358	35	48	67	93	129	178
22	CHATTISGARH	227	244	260	274	287	298	190	265	370	515	715	993	50	70	97	135	187	259
23	MADHYA PRADESH	668	726	783	835	880	915	536	749	1,046	1,458	2,030	2,824	140	195	272	377	523	724
24	GUJARAT	553	593	631	663	695	722	924	1,297	1,821	2,558	3,593	5,047	338	472	657	912	1,263	1,748
25		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	MAHARASHTRA	1,053	1,132	1,206	1,275	1,337	1,390	1,895	2,667	3,760	5,309	7,502	10,609	469	655	911	1,264	1,751	2,424
28	ANDHRA PRADESH	810	850	886	918	942	979	1,028	1,440	2,017	2,825	3,954	5,534	215	299	416	578	801	1,109
29	KARNATAKA	565	596	626	650	671	697	826	1,159	1,625	2,280	3,200	4,489	208	291	404	561	778	1,077
30	GOA	15	18	20	23	23	24	50	70	99	139	196	276	21	29	40	56	77	107
31		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	KERALA	334	346	357	366	373	388	460	648	914	1,291	1,825	2,582	90	125	174	242	336	465
33	TAMIL NADU	653	676	695	709	719	747	982	1,382	1,947	2,747	3,880	5,483	292	408	567	787	1,091	1,510
34	PONDICHERRY	11	14	17	21	22	23	32	44	63	88	124	175	18	25	34	48	66	92
35	A&N ISLANDS	4	5	6	6	7	7	7	10	14	19	27	38	2	2	3	4	6	8
	Total	11,170	11,971	12,731	13,433	14,024	14,576	13,260	18,597	26,084	36,584	51,311	71,966	3,099	4,324	6,015	8,349	11,569	16,012

Source: JICA Study Team

6.3 FREIGHT DEMAND FORECAST

The JICA Study Team carried out demand forecast of the Eastern and Western Corridors, including not only DFC but also the existing lines.

6.3.1 Methodology

(1) Target Year of the Projection

In the Task 0&1, the future traffic was projected for every five years from the year 2011-12 up to 2031-32, namely, 2011-13, 2016-17, 2021-22, 2026-27, and 2031-32. It was assumed that the year 2011-12 would be the beginning year of the DFC operation in Task 0&1. Note that different target years were applied in Task 2 after the project schedule was reviewed in this Study.

(2) Source of the Demand Forecast

The most important material were PETS-I& II report, train O/D provided by CRIS (Centre for Railway Information Systems), and Yearbooks of Indian Railways. The JICA Study Team carried out Roadside Interview Survey and Company Interview Survey for the modeling.

The train O/D of CRIS was taken from FOIS (Freight Operations Information System). The data set contains full records of freight trains operated last three years, and each record has following information:

1) Name of the train
2) Departure station and arrival station
3) Commodity
4) Wagon type
5) No. of wagon
6) Total tonnage
7) Departure time and arrival time

(3) Flow of the Projection

The demand forecast model in Task-1 consists of four steps: transport generation, transport distribution, modal choice, and traffic assignment. The concept is similar to the traditional four-step demand model. Figure 6-3 illustrates the work flow of the projection. Modal split was not applied for non-container projection because the commodity-wise generation models were developed so that it could estimate commodity generation by rail directly. Commodities were categorized into eight groups such as coal, cement, POL, fertilizer, foodgrain, steel, iron ore, and others. For coal transport in the Eastern Corridor, the future coal transport that was projected in PETS-I was incorporated into the state O/D. Container projection was carried out for the Western Corridor with modal split.

(4) Study of Intermodal Research Unit

Note that the forecast in this report conforms to the forecast “Study on Development of Intermodal Freight Transport Strategy, March 2007”, by Inter-modal Research Unit of the JICA Study Team.

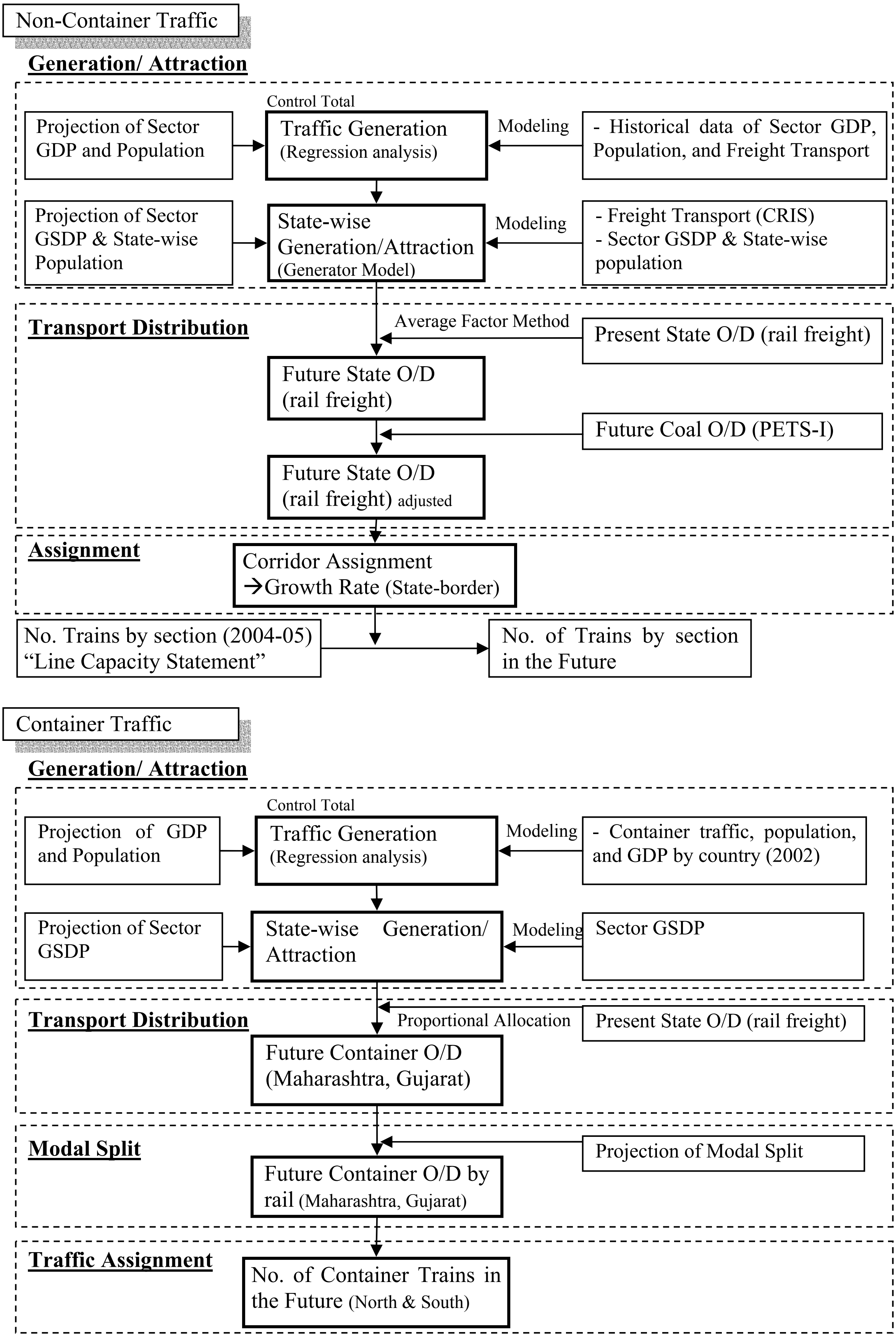


Figure 6-3 Flow of Demand Forecast of Freight Train in this Study

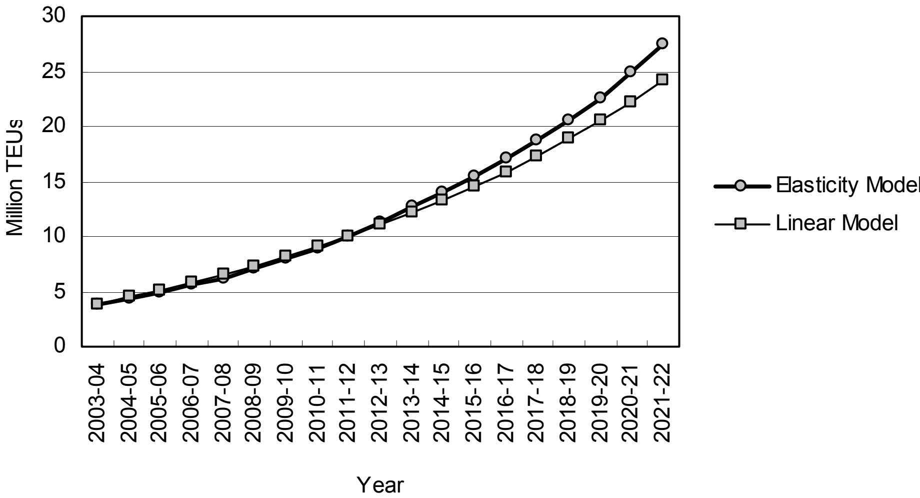
6.3.2 Container Traffic

(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 CAGR of 18.31%.

In this Study, the total container throughput at all ports in India was estimated by two methods, namely, the time series analysis and the cross country analysis.

In the time series analysis, a linear regression analysis was carried out using container traffic and GDP data of India from 1998-99 to 2003-04. The result of analysis is: Y = 0.5931X-4572 (r^2= 0.99), where Y=Container traffic in 000TEU, X= GDP at 1993-94 constant prices. A similar projection was applied in PETS-II using elasticity model. Figure 6-4 illustrates the results of the linear model in this Study and the elasticity model in PETS-II.



Note: Elaborated by JICA Study Team. GDP growth rate: CAGR = 7.0%
Source: Container traffic – "Rail Transport Logistics Study for the Planned Development of J.N.Port, RITES LTD.". GDP – Central Statistical Organisation (CSO)

Figure 6-4 Projection of Container Traffic by Elasticity Model and Linear Model

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

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

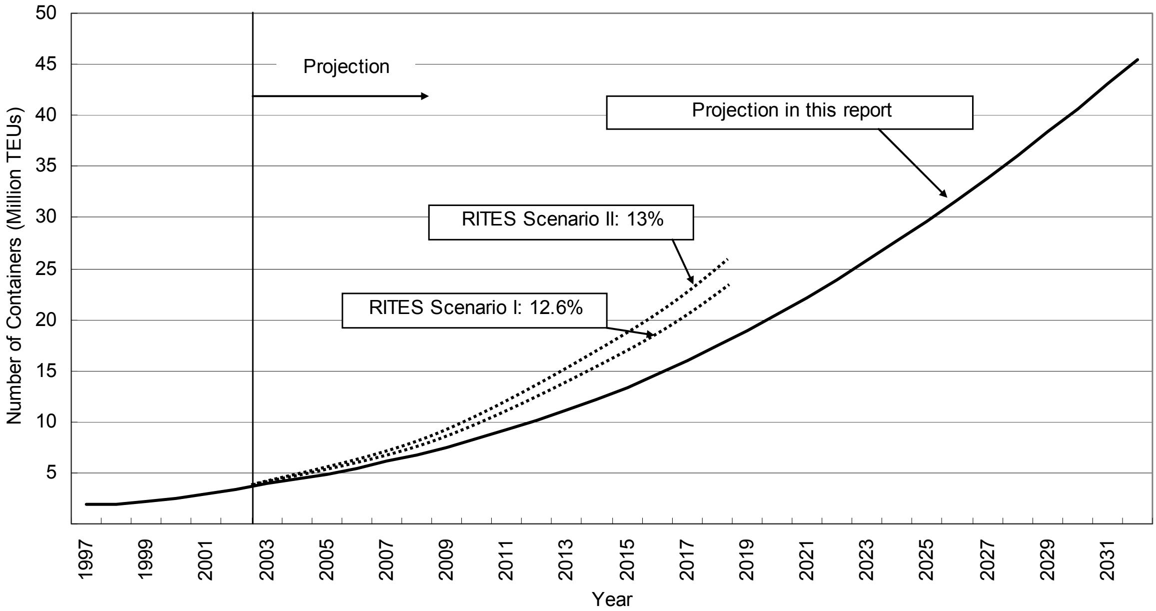
where, CONT = container throughput in million tonne per year
GDP = nominal gross domestic product in million US dollars
POP = population in million

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 6-5 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

[1] "National Maritime Development Plan, 2005"

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 6-5 Projection of Container Throughput at All Indian Ports

(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 production by state, the future state-wise container traffic was computed as shown in Table 6-3. 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. Note that these containers would be transported by not only rail but also vide trucks and through coastal shipping.

Table 6-3 Projection of Container Throughput

Unit: ‘000 TEU

	2003-04		2021-22		2031-32	
	Traffic	Rate	Traffic	Share*	Traffic	Share*
Maharashtra	2,466	62.1%	8,049	36.3%	15,304	35.5%
Gujarat	243	6.1%	7,031	31.7%	13,395	35.1%
All India	3,973	100%	22,149	100%	43,052	100%

Source: PETS-I (2003-04), Estimation by JICA Study Team (2021-22, 2031-32)

Note: * The share of state I in the year y was calculated by $R(i,y) = \frac{SCONT(GSDP_i(y))}{\sum_k SCONT(GSDP_k(y))} \times 100$

Where, SCONT(GSDPi(y)) = state-wise container traffic model; GSDPi(y)= GSDP of state in the year

(3) Modal Split

The JICA Study Team carried out a roadside interview survey for trucks at six state borders in July – August, 2006. From the survey result and CRIS freight O/D, the present railway share from/to JNPT was estimated as shown in Table 6-4.

Table 6-4 Modal Share of Container Transport from/ to JNPT

Within Maharashtra State	Outside of Maharashtra State	
	Truck	Rail
30%*	42%	28%

Source: Estimation by JICA Study Team
Note: *Since travel distance within Maharashtra is short, railway share might be small.

The result shows that the present rail share is approximately 30%. It is clear that if the DFC existed at present, the rail share would be higher than 30%. According to PETS-I, about 50% of container traffic at ports is transported for short distance below 300 km. Since the rail share at all ports in the western region was 23.7% in 2003-04, rail transport accounted for 47.4% of the container transport whose travel distance exceeds 300 km. If the rail share over 300 km is 70%, the rail share to the total container traffic becomes 30%.

On the other hand, the Inter-modal Research Group has evaluated the preliminary modal split model using the roadside interview survey and the company interview survey, and further estimated the DFC share to be about 35%.

Judging from the above, rail share from/to Maharashtra and Gujarat was assumed to be 35% and 45%, respectively, and container traffic by rail was projected as shown in Table 6-5.

Table 6-5 Projection of Container Traffic for 2021-22 and 2031-32

State Name	Year	Total Container Traffic (000 TEUs)	Rail Share	Container Traffic by Rail (000 TEUs)	No. of Container Trains per Day
Maharashtra	2021-22 2031-32	8,049 15,304	35%	2,817 5,356	94.9 180.3
Gujarat	2021-22 2031-32	7,031 13,395	45%	3,164 6,028	106.5 203.0

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

Projection for intermediate years was computed by the linear interpolation between two estimations of 2006-07 and 2021-22 as follows:

Table 6-6 Projection of Container Traffic for 2011-12 and 2016-17

State Name	Item	2004-05	2011-12	2016-17	2021-22
Maharashtra	Total (000 TEUs)	2,589	4,837	6,443	8,049
	Rail Share	25%*	27%	32%	35%
	by Rail (000TEUs)	750*	1,306	2,062	2,817
	No. of Trains **	12.6	22.0	34.7	47.4
Gujarat	Total (000 TEUs)	676	3,291	5,161	7,031
	Rail Share	11%*	43%	44%	45%
	by Rail (000TEUs)	75*	1,415	2,271	3,164
	No. of Trains **	1.3	23.8	38.2	53.3

Source: Estimation by JICA Study Team
Note:* Consultant's estimation based on statistics of recent years
**: No of trains per day per direction

It was assumed that the present origin-destination pattern of container traffic would be the same in the future. The ratios of container traffics by rail between Gujarat and other states to the total generation and attraction of the traffics in Gujarat are shown in the following table, as well as the ratio of Maharashtra.

Table 6-7 O/D Pattern of Container Traffic for the Projection

Unit: %

State	Gujarat		Maharashtra	
	From Gujarat	To Gujarat	From Maharashtra	To Maharashtra
Punjab	1.61	1.99	5.18	4.54
Haryana		0.06		
Delhi	4.76	7.97	23.93	20.23
Rajasthan	0.51	0.51	1.67	3.02
Uttar Pradesh	1.48	0.26	1.31	3.09
Bihar	1.29			
West Bengal	3.92	1.99	0.51	0.16
Madhya Pradesh			1.00	0.79
Gujarat	3.15	3.15	4.77	5.63
Maharashtra	33.87	28.73	10.25	10.25
Andhra Pradesh	0.77	0.77	1.61	1.69
Karnataka	0.26	0.45	0.01	0.02
Kerala	0.06			0.02
Tamil Nadu	1.93	0.51	0.19	0.12
Subtotal	53.60	46.40	50.44	49.56
Total	100.0		100.0	

Note: Computed from CRIS O/D (2005-06) by JICA Study Team

(4) Equivalent Trucks for the Container Traffic

If trucks had to carry all the container traffic at ports of Maharashtra and Gujarat, the number of required trips by container trucks would be 12,315 trips per day in 2011-12, 22,848 trips in 2021-22, and 43,483 trips in 2031-32 (2 TEUs per truck). Assuming that half of them are out-going trips beyond each state, it is computed that 10,000 container trucks will move for one direction in 2031-32. This means that when rail does not carry international containers at all, a 6-lane equivalent highway which is required exclusively for container trucks.

(5) Container Traffic of Eastern Corridor

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

(6) 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 assumed a moderate annual growth rate of 2% for domestic containers as same as in PETS-II.

Table 6-8 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

6.3.3 Coal Traffic

(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 6-9 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.

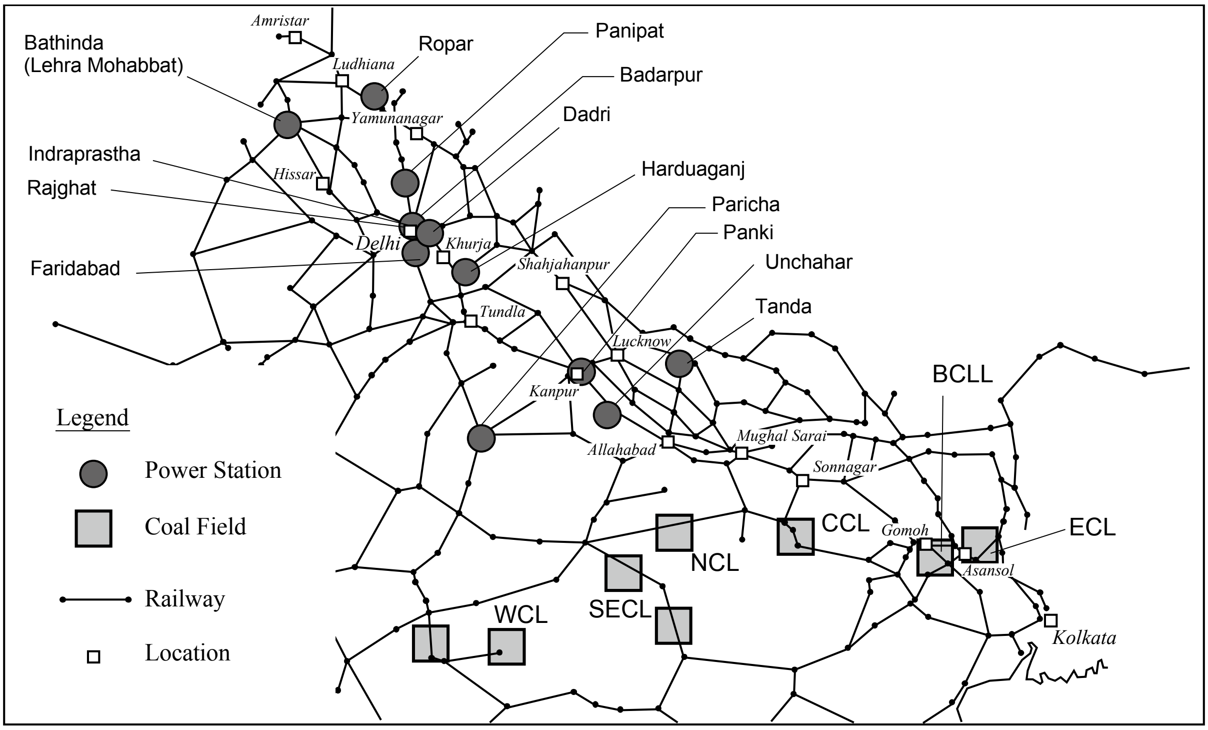
Table 6-9 List of Thermal Power Stations

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

(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.



Note: Elaborated by JICA Study Team

Figure 6-6 Location of Thermal Power Plants and Coal Fields

(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 6-10. 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 6-10 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

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 6-11 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

Although PETS-II includes new information that was not analyzed in PETS-I, the result of PETS-I was incorporated into the projection in this report. For coal transport in the Eastern Corridor, traffic linkage of coal estimated in PETS-I shown in Table 6-12 was incorporated into the future state O/D matrices.

[1] Overview of Power Sector in India 2005, IndiaCore

Table 6-12 Distribution of Coal Transport

Unit: Million Tonne per Year

State	Year	Delhi	Haryana	Punjub	Uttar Pradesh
Power Plant		- Badarpur - Indraprastha - Rajghat	- Faridabad - Panipat - Yamunanagar	- Bhatinda - Lehra Mohabbat - Ropar - Govindwal Sahib	- Dadri - Harduaganj - Panki - Paricha - Unchahar - Tanda - Rosa - Chola
West Bengal (ECL)	04-05 11-12 16-17 21-22	0.48 0.48 0.48 0.48	- - - -	0.66 3.05 3.05 3.05	0.78 1.26 1.26 1.26
Jharkhand (BCCL)	04-05 11-12 16-17 21-22	0.3 0.3 0.3 0.3	1.82 2.16 2.16 2.16	1.12 1.12 1.12 1.12	3.41 5.93 5.93 5.93
Jharkhand (CCL)	04-05 11-12 16-17 21-22	3.78 3.78 3.78 3.78	2.07 6.16 9.16 11.16	5.52 8.98 11.98 13.98	11.10 21.72 27.72 31.72

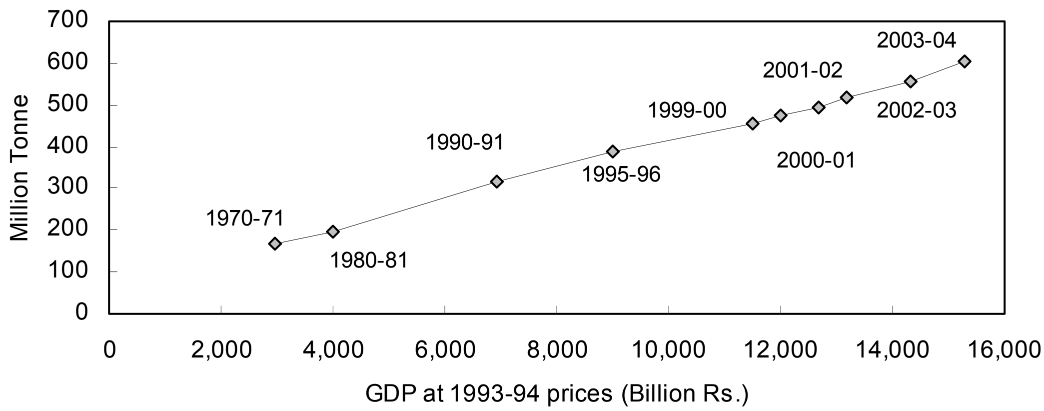
Source: PETS-I

The future coal demand for thermal power plants in 2031-32 was not estimated. Instead, CAGRs of coal transport on the Eastern Corridor from 2016-17 to 2021-22 was applied to the total coal transport on the Eastern Corridor.

6.3.4 Traffic Demand of Other Commodities

(1) Trip Production

Originating freight loading by Indian Railways has been correlating with GDP as shown in Figure 6-7. 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 6-13. The best formula was selected for each commodity type.



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

Figure 6-7 Relation between GDP and Freight Traffic by Rail

Table 6-13 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 6-14 shows the calculated compound annual growth rates (CAGRs) from years 2004-05 to 2031-32 and adopted explanatory variables for each commodity type.

Table 6-14 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*

Coal and POL: The projected growth rates of coal and POL are very much higher than other commodities. Although their correlation coefficients show good reliability of the models, the results were checked using other projections. For coal transport along the Eastern

Corridor, it was concluded that the projection in PETS-I would be proper. On the other hand, the growth rate of coal in the Western Corridor which was set as 5% was higher than other projections such as TERI (The Energy and Resources Institute) and Work Energy Outlook. The projection for POL was also higher. In this study, annual growth rates of 2.4% and 2.9% were applied for coal and POL in the Western Corridor, respectively, taking into account of these factors.

Coal requirement was computed based on the assumption that a 1,000 MW plant would consume 5 million tonne per year.

(3) Freight Traffic Distribution

The future state O/D matrices (34 zones) in year 2021-22 and 2031-32 were produced from the present O/D matrix that was elaborated from CRIS freight O/D and the projected state-wise generation and attraction. The average growth method was applied for non-container commodities.

6.3.5 Traffic Assignment

The estimated O/D matrices are based on 34 states, which is so simple that it is not proper to assign the O/D pairs to railway network in which a lot of originating points and destinations are located within a state. Instead of railway network, commodity-wise O/D pairs in the years 2021-22 and 2031-32 were assigned to inter-state corridors. The ratio of the future traffic volume to the present at state borders along the corridors was computed by commodity type from the assignment as shown in Table 6-15. Note that a different method was applied for the traffic assignment in Task-2.

Table 6-15 Traffic Volume Ratio (Future Traffic/Base Year Traffic) of Major Section

Corridor	State-Pair	Section	2004-05	2021-22	2031-32
Eastern Corridor	BH – UP	Sonnagar – Mughal Sarai	1.00	2.27	3.02
		Mughal Sarai – Allahabad	1.00	2.22	2.96
		Allahabad – Kanpur	1.00	2.28	2.93
	UP – HR	Kanpur – Tundla	1.00	2.10	2.75
		Tundla – Khurja	1.00	1.96	2.54
Western Corridor	MH – GU	Mumbai – Vadodara	1.00	2.23	2.96
	MP – RJ	Vadodara – Vayana	1.00	2.29	3.05
	RJ – UP	Vayana – Tughlakabad/North	1.00	2.29	3.05

Source: JICA Study Team

Note: The section-wise ratios in the Eastern Corridor were computed taking into account of the composition of commodity estimated in PETS-I because growth rate differed by commodity type.
BH=Bihar, UP=Uttar Pradesh, HR=Haryana, MH=Maharashtra, GU=Gujarat, MP=Madhya Pradesh, RJ=Rajasthan,

For container transport in the Western Corridor, traffic was assigned to the north and south routes taking into account of the location of ports and the existing railways as shown in Table 6-16. The result of the assignment does not necessarily suggest the desirable route for the DFC, and it should noted that traffic may change the route according to the DFC alignment. Although the number of trains is constant between Vadodara and Phulera in the assignment due to using simple state O/D, the actual number of trains between Vadodara and Palanpur must differ because ports in Gujarat such as Mundra Port connects at Palanpur in the same state. This was adjusted in estimating the sectional traffic below.

Table 6-16 Container Traffic Assignment to Rail Corridors

Unit: No. of Trains (average of up and down directions)

Route		Section	2021-22	2031-32
North & South	A	JN Port – Vadodara	51.2	97.4
South Route	B	Vadodara – Sawai Madhopur	31.0	59.0
	C	Sawai Madhopur – Tughlakabad	30.2	57.4
North Route	D	Vadodara – Phulera	39.8	75.8
	E	Phulera – Rewari	38.8	73.8
	F	Rewali – Delhi	33.6	64.0

Source: Estimation by JICA Study Team
Note: 90 TEU per train

Table 6-17 shows which origin-destination pairs were allocated to the routes (A – F). For example, container traffic between Gujarat (GU) and Punjab was allocated to the section of E (Phulera - Rewari), while traffic from/to Madhya Pradesh was not allocated to this section.

Table 6-17 O/D pairs for Container Traffic Assignment

State	Section					
	A	B	C	D	E	F
Punjab	MH	GU	MH	GU	GU	
Haryana, Delhi, Rajasthan, Uttra Pradesh, Bihar, West Bengal, Orissa	MH	GU	MH	GU	GU	GU
Madhya Pradesh	MH	GU		GU		
Gujarat	MH			MH	MH	MH

Source: Estimation by JICA Study Team
Note: MH= Maharashtra, GU=Gujarat

6.3.6 Cross-Section Traffic

The future number of freight trains was calculated by multiplying the base year traffic by the traffic volume ratio in Table 6-18. Note that this method was based on the precondition that the present net weight of loading would not change for the projection periods. The base year traffic was taken from "Line Capacity Statement". Fiscal year of 2004-05 was regarded as the base year of the projection. Here is a table which shows the number of freight trains in the major sections of the Eastern Corridor.

Table 6-18 No. of Freight Trains in the Eastern Corridor in the Future

Unit: No. of Trains (average of up and down directions)

Route	Section	2004-05	2021-22	2031-32
Sonnager – Khurja	Sonnagar – Mughal Sarai	45.2	103	137
	Mughal Sarai – Allahabad	37.2	82	110
	Allahabd – Kanpur	34.8	79	102
	Kanpur – Tundla	35.9	75	99
	Tundla – Khurja	30.4	60	77
Delhi - Ludhiana	Delhi – Ambala	22	36	47
	Ambala - Ludhiana	12	20	26

Source: Estimation by JICA Study Team
Note: This is a summary table. The numbers represent traffics in major sections.

In the Western Corridor, the numbers of containers and non-containers trains were computed separately. Here is a table which shows the numbers of container and non-container trains.

Table 6-19 No. of Freight Trains in the Western Corridor

Unit: No. of Trains (average of up and down directions)

Route	Section	2004-05		2021-22		2031-32	
		Non-Container	Container	Non-Container	Container	Non-Container	Container
North & South	JNPort – Udhna	11.3	8.6	25	51.2	33	97.4
	Udhna – Vadodara	18.2	8.6	41	51.2	54	97.4
South Route	Vadoda – Ratlam	25.9	6.8	59	31.0	79	59.0
	Ratlam – Kota	13.1	6.5	30	31.0	40	59.0
	Kota–Sawai	14.7	6.5	34	31.0	45	59.0
	Sawai – Tughlakabad	10.8	5.5	25	30.2	33	57.4
North Route	Vadodara – Palanpur	19.0	1.5	43	28.7*	58	54.6*
	Palanpur – Phulera	7.9	0.3	18	39.8	24	75.8
	Pulera – Rewari	6.7	0.0	15	38.8	20	73.9
	Rewari – Delhi	8.7	0.0	20	33.6	26	64

Source: Estimation by JICA Study Team
Note: This is a summary table. The numbers represent traffics in major sections.
*: The number was adjusted using the proportion of the traffic in the section to Palanpur – Phulera (72%, taken from PETS-I report)

6.3.7 Freight Transport Output in Tonne-Km

Since demand forecast of tonne-km is necessary in the other chapters, the number of freight trains estimated in Table 6-18 and Table 6-19 was converted to tonne-km using the following conversion units.

- Net loading tonne per container train = 1,213 tonne (JICA Study Team estimation)
- Net loading tonne per non-container train = 2,395 tonne (Average of CRIS freight O/D)
- Percentage of empty trains = 20%

The information about empty trains on sections along the corridors was not necessarily available, and then empty rate was assumed to be 20%, which was computed from the data in PETS-I for the Western Corridor. From this assumption, the future transport output in the Eastern and Western Corridors was estimated as shown in Table 6-20.

Table 6-20 The Future Tonne-Km by Corridors (Both Directions)

Unit: Billion Tonne

Corridor	Section	2004/05	2021/22	2031/32
East	Sonnagar – Khurja	37.8	82.0	107.6
	Khurja – Ludhiana*	10.7	19.7	26.0
West	Mumbai – Vadodara	10.2	34.0	55.5
	Vadodara – North	11.0	54.7	90.0
	Vadodara – South	28.5	77.7	117.0

Source: Estimation by JICA Study Team
Note:* Khurja – Saharanpur – Ambala, Delhi – Ambala – Ludhiana

6.4 PASSENGER DEMAND FORECAST

The purpose of the passenger demand forecast is to provide the future demand in passenger transport for capacity analysis. The number of passengers carried by Indian Railways in 2004-05 was 5,378 million passengers, and the passenger-km amounted to 576 billion.

O/D data of railway passenger is not available, because Indian Railways does not keep all ticket sales data with information on boarding and alighting. On the other hand, the Centre of Railway Information System (CRIS) keeps ticket reservation data. CRIS provided JICA Study Team with passenger data of the last year, which contains O/D information of 218 million passengers (4% of the total passenger). The data includes almost all data of upper class traffic and second class traffic for express/mail trains. Most of the second class traffic for ordinary trains is not included in this data.

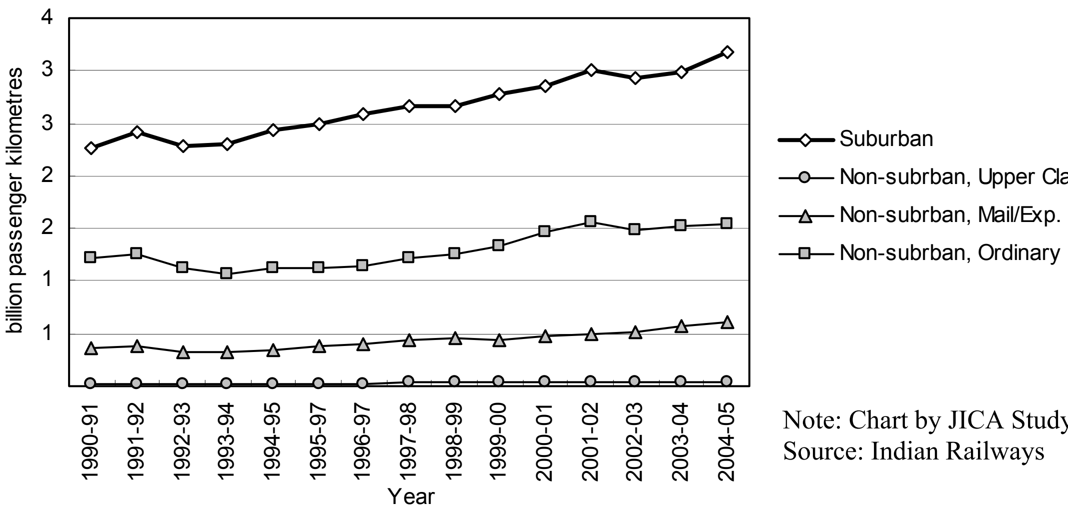
6.4.1 Trend Analysis

Railway passenger demand has been increasing year by year. The total number of passengers has increased at a CAGR of 3.2% for the last 10 years (from 1994-95 to 2004-05). The growth rate of the number of non-suburban passengers in CAGR was 4.0%, while that of suburban passengers was 2.7%. Passenger-km showed higher growth rate than the number of passengers. Passenger-km has increased at a CACR of 6.1% for the same period. The growth rate of non-suburban passenger transport in passenger-km was higher than that of suburban passenger transport – the former was 6.5% and the latter was 4.3% in the same period. There was a drop of 2.4% in the total number of passengers in 2002-03.

Table 6-21 CAGR of GDP, Population, and Railway Passenger Traffic for the Last 10 Years

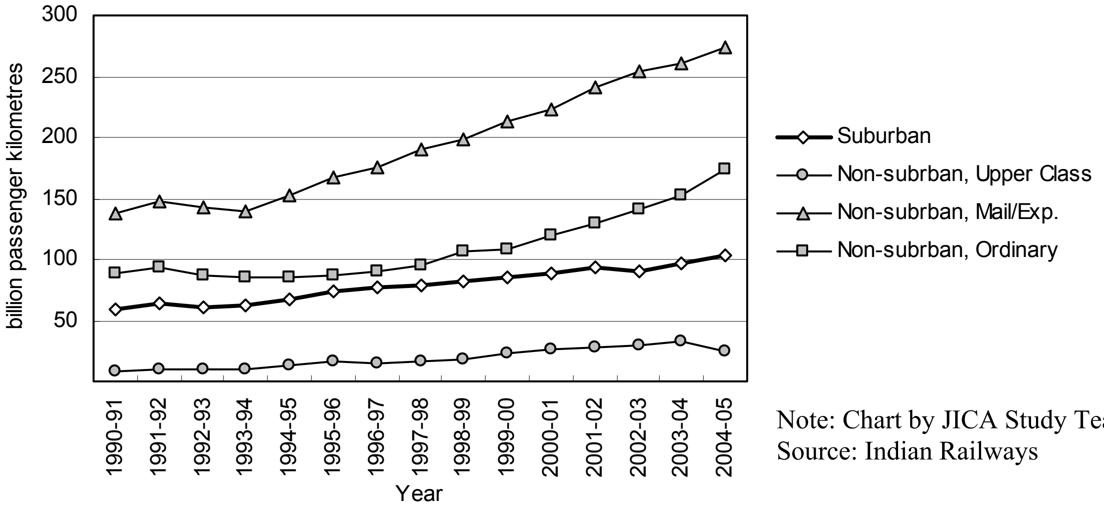
GDP	Population	No. of Passenger			Passenger-km		
		Suburban	Non-suburban	Total	Suburban	Non-suburban	Total
5.9%	1.7%	2.7%	4.0%	3.2%	4.3%	6.5%	6.1%

Source: Statistical Abstract, CSO (mosip.gov.in), Indian Railways Statistical Yearbook



Note: Chart by JICA Study Team
Source: Indian Railways

Figure 6-8 Number of Passengers originating from 1999-00 to 2005-05



Note: Chart by JICA Study Team
Source: Indian Railways

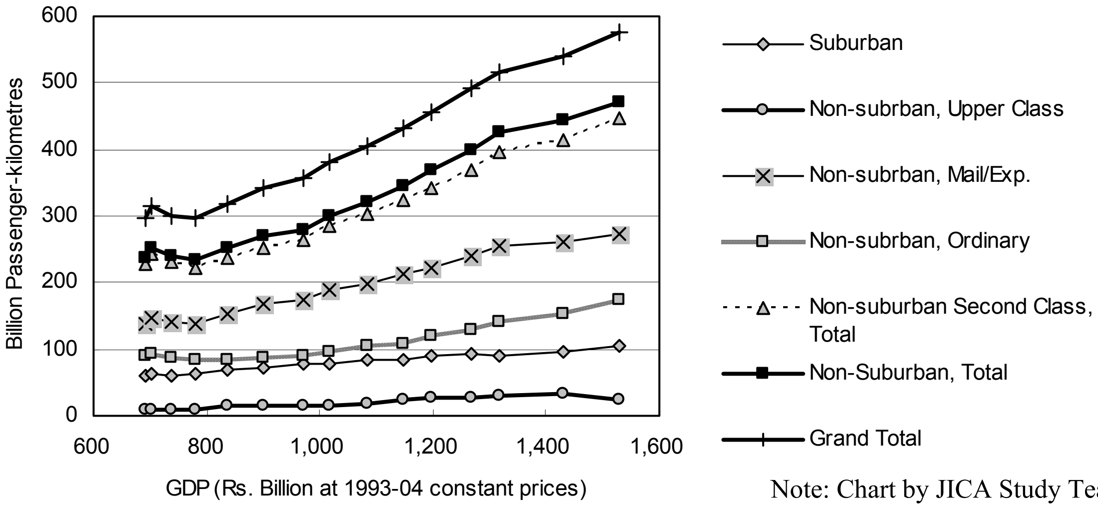
Figure 6-9 Passenger-km from 1999-00 to 2005-05

GDP growth in year 2003-04 was significant at a growth rate of 8.5% (1993-04 current prices), while growth rates of the number of passenger and passenger-km were 2.8% and 5.1%, respectively. Figure 6-10 illustrates a change in the slope of some lines in 2002-03. This means that passenger demand growth has not caught up with GDP growth since 2002-03. The reasons of the change might be:

1) Growth in competitive transport modes (structural change of modal share), and

2) Capacity constraints of passenger service of railway.

Indian Railways enhanced the capacity of passenger transport to response to the increasing demand. Wagon-km of suburban and non-suburban have increased at CACR of 3.1% and 4.0%, respectively, during the same period. The increase rates of train-km of them were 2.4% and 3.5%, respectively.



Note: Chart by JICA Study Team
Source: Indian Railways

Figure 6-10 Relationship between GDP and Passenger-kilometre of Indian Railways

6.4.2 Modal Share Analysis

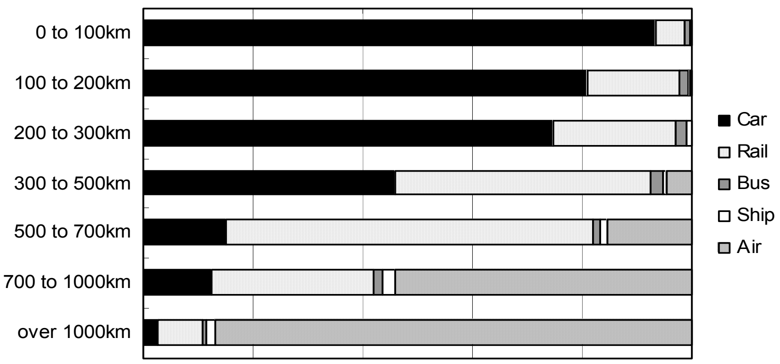
Increase in air passenger is significant in recent times. The average passenger load factor of domestic flights is increasing: it was 64.8% in 2002-03, 65.5% in 2003-04, and 68.4% in 2004-05. Some discount air tickets seem to be attractive in view of price compared to the first class tickets of express trains. For example, 1st class ticket of Rajdhani between Delhi and Mumbai cost Rs. 3,500 for its 16 hours and 40 minutes travel, while a discount economy ticket of Indian Airlines costs Rs. 4,620 for 1 hour and 25 minutes flight. Railway statistic shows that the average travel distances of upper class non-suburban and second class express/mails are decreasing recently. This implies that modal shift from rail to air has already begun for long distance travels.

Table 6-22 Comparison of Air and Rail between Major Cities

	Air (August 2006)	Rail
Delhi → Mumbai	1,137km Indian Airlines: 1h 25m Economy: Rs. 10,390 Level-4 Economy: Rs. 4,620	1,388km Rajdhani(2952): 16h 40m 1st Class: Rs. 3,500 3A: Rs. 1,495
Delhi → Kolkata	1,309km Indian Airlines: 1h 55m Economy: Rs.11,740 Level-4 Economy: Rs.5,170	1,441km Rajhani(2302): 15h 45m 1st Class: Rs.3,565 3A: Rs.1,520
Mumbai → Ahmedabad	442km Indian Airlines: 1h Economy: Rs. 5,730 Level-4 Economy: Rs.2970	492km Shatabdi (2009): 7h 10m 1st Class: Rs.1,330 CC: Rs.695
Delhi → Jaipur	233km Indian Airlines: 40m Economy Class: Rs. 4,165 Level-4 Economy: Rs.1,655	308km Shatabdi (2015): 4h 30m 1st Class: Rs.905 3A: Rs.465

Source: Indian Airlines (indian-airlines.nic.in), Indian Railways

Increase in car ownership will also reduce railway's share in passenger transport. The figure below illustrates modal share depending on travel distance in Japan. This illustrates car is the dominant mode in developed countries when the travel distance is less than 300 km. Railway's share is significant when the travel distance is between 500 km and 700 km. Over 700 km, air transport is the major mode. Inter-city buses will emerge as strong competitor of passenger transport with the travel distance less than 300 km. Although the modal share in Japan can not be applied to Indian transport sector, this implies the future role of Indian Railways.



Source: Ministry of Land Infrastructure and Transport, Government of Japan

Figure 6-11 Modal Share depending on Travel Distance

6.4.3 Future Demand in Passenger Transport

The number of railway passengers has been increasing for the last 10 years as well as the average lead. Railway is an important transport mean for the poor, providing low fares especially for the second class. As long as Indian Railways continues its existing fare policy, the number of railway passengers will increase in proportion to increase in population. An annual growth rate of 2% was assumed for the passenger demand in PETS-I. This growth rate is relatively conservative considering the past trend. In the JICA Study, it is assumed that passenger demand along the Corridors will increase at the same rate of the total demand in passenger traffic of Indian Railways. Several pairs of regression models and independent values such as GDP, population, and year, were tested to formulate demand forecast models for the number of passenger originating and for passenger-km. Since suburban demand and non-suburban demand show different trends recently, these two traffics were analyzed separately. The best model of those is illustrated as:

		Number of Passenger		**Average Lead**
Passenger - km	=	- Liner regression model - Variable = Population	×	- Linear regression model - Variable = Year

Number of Passenger Originating

Using past data from the years 1990-01 to 2004-05, coefficients and constant values of the model to estimate the number of passenger originating are computed as follows:

$NP_{SU} = 3.983\ P - 1212\ (r^2 = 0.97)$
$NP_{NS} = 4.206\ P - 2370\ (r^2 = 0.97)$

where, NPSU = The number of passengers (originating) of suburban trains
NPNS = The number of passengers (originating) of non-suburban trains
P = Population

From these formulas, the numbers of passengers of suburban and non-suburban trains in the future are computed as shown in the table below.

Table 6-23 Demand Forecast of Number of Passenger Originating

(Unit: Million Passengers)

Year	2006-07	2011-12	2021-22	2031-32
Suburban	3,266	3,597 (1.9%)	4,208 (1.6%)	4,690 (1.1%)
Non-Suburban	2,359	2,708 (2.8%)	3,353 (2.2%)	3,862 (1.4%)
Total	5,625	6,305 (2.3%)	7,561 (1.8%)	8,552 (1.2%)

Note: Percentages in brackets are CAGR from the previous period of the left column.
Source: JICA Study Team

Average Lead

The average lead is the average travel distance which is calculated from passenger-km divided by the number of passengers. The models for average lead of suburban and non-suburban trains are:

$L_{SU} = 0.4571\ Y - 883$
$L_{NS} = 4.344\ Y - 8494$

where, LSU = The average lead of suburban trains
LNS = The average lead of non-suburban trains
Y = Year

Table 6-24 Estimation of Average Lead of Passenger Transport

	2006-07	2011-12	2021-22	2031-32
Suburban	33.7 km	35.9 km	40.5 km	45.1 km
Non-Suburban	220 km	242 km	285 km	329 km

Source: JICA Study Team

Passenger-km

Passenger-km is generated from the number of passengers multiplied by the average lead. The table below shows the estimation of passenger-km in the future. The CAGRs are calculated to be 4.5% from 2006-07 to 2011-12, 3.7% from 2011-12 to 2021-22, and 2.8% from 2021-22 to 2031-32. From 2006-07 to 2011-12, it is calculated to be 4.0%.

Table 6-25 Demand Forecast of Passenger-km and Growth Ratio

Unit: Billion Passenger Km

Year	2006-07	2011-12	2021-22	2031-32
Suburban	109.9 (1.0)	129.3 (1.18)	170.5 (1.55)	211.5 (1.92)
Non-Suburban	519.0 (1.0)	654.8 (1.26)	956.4 (1.84)	1,269.3 (2.45)
Total	629.0 (1.0)	784.1 (1.25)	1,126.9 (1.79)	1,480.7 (2.35)

Note: Percentages in brackets are CAGR from the previous period of the left column.
Source: JICA Study Team

Note that this forecast does not consider the capacity constraints of the existing railway system. In this forecast, the service level of the existing passenger rail is assumed to be provided to all the necessary passengers.

6.4.4 Cross-Section Passenger Traffic

The number of passenger trains was estimated according to a diagram below.

No. of trains in the projection year	=	No. of passengers in the base year	×	Growth ratio for the projection year (Table 5.1.24)	÷	Average passenger occupancy in the projection year

No. of passenger in the base year

This was calculated as:

No. of trains of the section × Average passenger occupancy

For the number of trains in the base year (2004-05), data was obtained from "Line Capacity Statement" of each Zonal Railways. The average passenger occupancy (the number of passenger per train) in 2004-05 was estimated to be 1,154 (1,687 for suburban train, 1,037 for non-suburban train) based on "Year Book 2004-05" of Indian Railways.

Average Passenger Occupancy in the projection year

Based on a trend analysis for passenger transport statistics of Indian Railways, average passenger occupancy in the future was estimated. The model is:

$$PO_{SU} = 35.35\,Y - 69{,}196 \quad (r^2 = 0.89)$$
$$PO_{NS} = 30.03\,Y - 59{,}146 \quad (r^2 = 1.00)$$

Where, PO_{SU} = The average passenger occupancy for suburban trains
PO_{NS} = The average passenger occupancy for non-suburban trains
Y = Year

This model was applied to suburban and non-suburban each up to 2021-22 and the average passenger occupancy after the year was assumed to be constant. The weighted average was calculated by applying the projected passenger-km. Table 6-26 shows the result.

Table 6-26 Projected Average Passenger Occupancy

Unit: No. of passengers/ train

Year	2004-05	2011-12	2016-17	2021-22	2031-32
Suburban	1,687	1,905	2,081	2,258	2,258
Non-Suburban	1,037	1,247	1,367	1,547	1,547
Average	1,154	1,355	1,505	1,655	1,649

Source: Estimation by JICA Study Team

As a result, the numbers of trains in the major sections of the East and Western Corridors were computed as shown in Table 6-27 and Table 6-28, respectively.

Table 6-27 No. of Passenger Trains in the Eastern Corridor

Unit: No. of Trains (average of up and down)

Route	Section	2004-05	2021-22	2031-32
Sonnager – Khurja	Sonnagar – Mughal Sarai	21	29	38
	Mughal Sarai – Allahabad	31	57	76
	Allahabd – Kanpur	38	52	68
	Kanpur – Tundla	55	75	99
	Tundla – Khurja	47	64	85
Delhi - Ludhiana	Delhi – Ambala	35	48	63
	Ambala – Ludhiana	39	53	70

Source: Estimation by JICA Study Team
Note: This is a summary table. The numbers represent traffics in major sections.

Table 6-28 No. of Passenger Trains in the Major Sections of the Western Corridor

Unit: No. of Trains (average of up and down)

Route	Section	2004-05	2021-22	2031-32
North & South	JNPort – Udhna	47	64	85
	Udhna – Vadodara	49	66	87
South Route	Vadoda – Ratlam	25	34	45
	Ratlam – Kota	23	31	41
	Kota – Sawai	27	37	49
	Sawai – Tughlakabad	16	22	29
North Route	Vadodara – Palanpur	47	64	84
	Palanpur – Phulera	17	23	31
	Phulera – Rewari	14	19	25
	Rewari – Delhi	17	34	45

Source Estimation by JICA Study Team
Note: This is a summary table. The numbers represent traffics in major sections.

Passenger- km of the corridors was also estimated as shown in Table 6-29.

Table 6-29 Future passenger km by corridor (billion passenger km)

Corridor	Section	2004-05	2021-22	2031-32
East	Sonnagar – Khurja	48.3	94.5	124.2
	Delhi – Ludhiana	12.9	25.2	33.2
West	Mumbai – Vadodara	15.1	29.6	38.9
	Vadodara – North	15.8	30.9	40.6
	Vadodara – South	22.7	44.4	58.4

Source: Estimation by JICA Study Team

6.5 CORRIDOR TRAFFIC

Corridor traffic was summarized from the result of freight and passenger train projections. In addition to freight and passenger trains, some non profit-generating trains are operated. Past data (Line Capacity Statement) shows that the number of this type of trains has not increased so much. In projection, the annual growth rate of 1% was assumed for these trains.

Table 6-30 and Table 6-31 show the summary of the results. Details with passenger trains and freight trains of the projection were shown in Tables 5-31 to 5-34. It should be noted that the projection did not consider capacity constraints of railway lines. The traffic volume with consideration of capacity constraints will be projected after demand-capacity analysis.

Table 6-30 No. of Trains in the Eastern Corridor

Unit: No. of Trains (average of up and down)

Route	Section	2004-05	2021-22	2031-32
Khurja - Sonnagar	Sonnagar – Mughal Sarai	74	142	187
	Mughal Sarai – Allahabad	80	141	187
	Allahabd – Kanpur	74	132	171
	Kanpur – Tundla	92	151	199
	Tundla – Khurja	78	125	163
Delhi- Ludhiana	Delhi – Ambala	57	84	110
	Ambala – Ludhiana	51	74	97

Source: Estimation by JICA Study Team

Table 6-31 No. of Trains in the Western Corridor

Unit: No. of Trains (average of up and down)

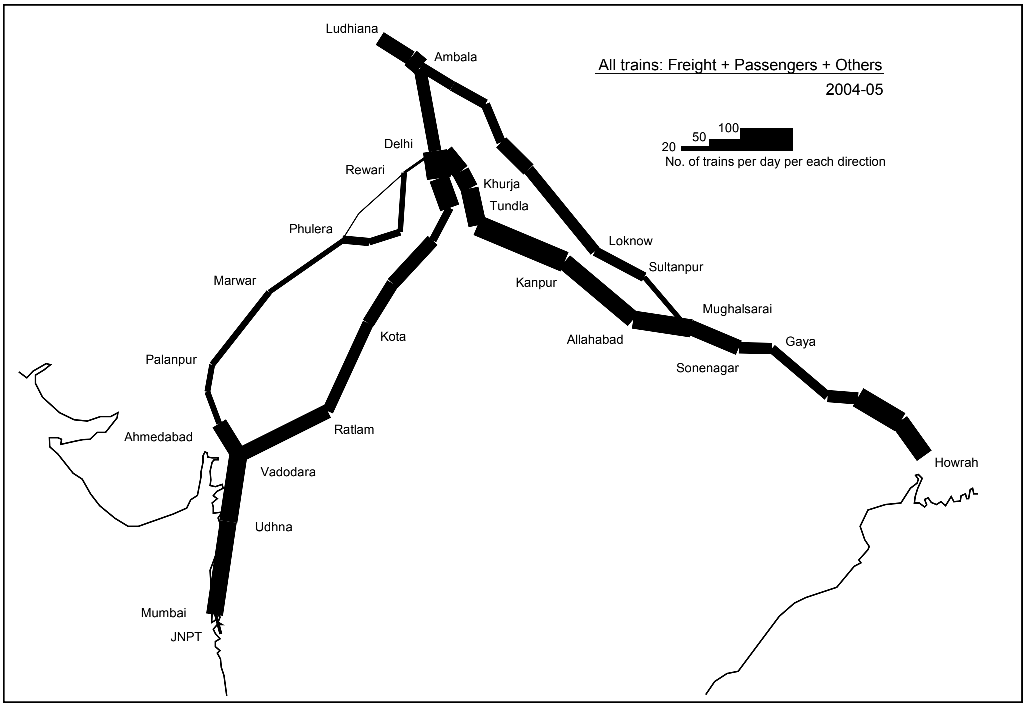
Route	Section	2004-05	2021-22	2031-32
South & North	JNPort – Udhna	70	145	220
	Udhna – Vadodara	78	136	242
South Route	Vadoda – Ratlam	64	132	191
	Ratlam – Kota	47	97	146
	Kota – Sawai	53	108	159
	Sawai – Tughlakabad	34	79	122
North Route	Vadodara – Palanpur	70	139	200
	Palanpur – Phulera	27	83	133
	Phulera – Rewari	22	74	121
	Rewari – Delhi	24	74	118

Source: Estimation by JICA Study Team

Figure 6-13 illustrates the section-wise traffic in year 2031-32. Comparing the future traffic with the existing traffic illustrated in Figure 6-12, increase in traffic volume of Western Corridor will be large because of increase in container traffic.

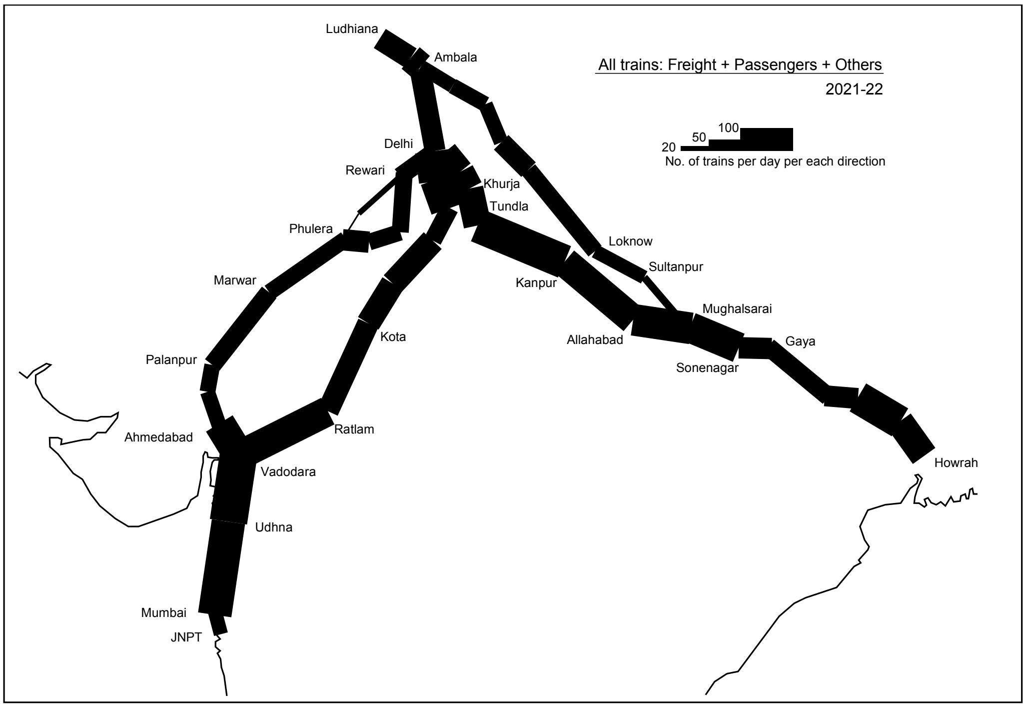
Section-wise traffic flow is also illustrated in bar charts in Figure 6-14.

Note: The results of this Chapter were used for alternative analysis in Task-1. The demand forecast was revised in Task-2 for detail analysis. However, the difference of the results was not significant enough to change the conclusion of Task-1.



Source: Elaborated by the JICA Study Team based on "Line Capacity Statement" of each Zonal Railways

Figure 6-12 Number of trains by direction per day on the East and Western Corridor (2004-05)



Source: JICA Study Team

Figure 6-13 Number of trains by direction per day on the East and Western Corridor (2031-32)

Table 6-32 Projection of the Number of Trains on Eastern Corridor (Delhi - Howrah)

East Corridor South Route Average No. of Trains per day per direction

Section		Freight						Passenger						Total					
		2004-05	2011-12	2016-17	2021-22	2026-27	2031-32	2004-05	2011-12	2016-17	2021-22	2026-27	2031-32	2004-05	2011-12	2016-17	2021-22	2026-27	2031-32
Sonenagar	Dehri-on-Sone	49	79	94	107	117	142	25	29	31	34	39	45	74	108	126	142	156	187
Dehri-on-Sone	Mughalsarai	48	78	93	106	116	141	21	24	26	29	33	38	69	102	120	135	149	178
Mughalsarai	Jeonathpur	35	58	68	78	84	104	37	43	47	51	58	67	72	101	115	128	142	171
Jeonathpur	Chunar	37	61	72	82	88	109	38	44	48	52	60	68	75	105	120	134	148	178
Chunar	Mizapur	38	62	73	83	90	111	42	49	53	57	66	76	80	111	126	141	156	187
Mizapur	Cheoki West	38	62	73	83	90	111	42	49	53	57	66	76	80	111	126	141	156	187
Cheoki West	Naini	33	53	63	72	77	96	37	43	47	51	58	67	70	96	110	122	135	162
Naini	Allahabad	34	56	66	75	81	99	52	60	65	71	82	94	86	116	131	146	162	193
Allahabad	Bamrauli	37	64	74	82	87	105	37	43	47	51	58	67	74	107	120	132	145	171
Bamrauli	Fatehpur	35	62	71	79	85	102	37	43	47	51	58	67	72	105	118	130	143	169
Fatehpur	Chandari	35	63	72	80	85	103	38	44	48	52	60	68	73	107	120	132	145	171
Chandari	Kanpur	36	63	72	80	86	103	38	44	48	52	60	68	74	107	120	132	145	171
Kanpur	Juhiwest	43	69	80	89	95	117	68	79	86	93	107	122	111	148	165	182	202	239
Juhiwest	Panki	37	59	68	76	82	100	55	64	69	75	86	99	92	122	137	151	168	199
Panki	Shikohabad	37	59	68	76	82	100	55	64	69	75	86	99	92	122	137	151	168	199
Shikohabad	Tundla	37	60	69	77	83	102	55	64	69	75	86	99	92	124	138	153	169	201
Tundla	Tundla West	41	61	71	78	85	101	59	68	74	81	93	106	100	130	145	159	177	207
Tundla West	Barhan	31	47	54	60	65	78	48	56	60	66	75	86	79	103	115	126	140	164
Barhan	Aligarh	31	47	54	60	65	78	47	55	59	64	74	85	78	102	114	125	139	163
Aligarh	Khurja	31	47	54	60	65	78	48	56	60	66	75	86	79	103	115	126	140	164
Khurja	Dankaur	28	42	49	54	58	70	49	57	62	67	77	88	77	99	110	121	135	158
Dankaur	Dadri	28	42	49	54	58	70	51	59	64	70	80	92	79	101	113	124	138	162
Dadri	Ghaziabad	25	37	43	48	52	61	51	59	64	70	80	92	76	97	107	117	132	153

Source: JICA Study Team

Table 6-33 Projection of the Number of Trains on Eastern Corridor (North Route)

East Corridor North Route Average No. of Trains per day per direction

		Freight						Passenger						Total					
		2005	2011	2016	2021	2026	2031	2005	2011	2016	2021	2026	2031	2005	2011	2016	2021	2026	2031
Mughal Sarai	Varanasi	17.6	22	26	32	44	55	33.5	37	41	44	51	58	51	59	67	76	95	112
Varanasi	Zafarbad	10.2	13	15	18	25	31	24.5	27	30	32	37	42	35	40	45	50	62	73
Zafarbad	Sultanpur	7.3	9	11	13	17	21	15.5	17	19	20	24	27	23	26	29	33	40	48
Sultanpur	Uraitia	7.3	9	11	13	17	21	15.5	17	19	20	24	27	23	26	29	33	40	48
Uraitia	Dilkusha Cabin	12.1	15	18	21	28	35	31.5	35	38	41	48	54	44	50	56	62	76	89
Dilkusha Cabin	Lucknow	21.2	26	31	37	50	62	60.5	67	74	79	92	104	82	93	105	116	142	166
Lucknow	Rahimabad	15.0	19	23	28	39	49	32.0	36	39	42	49	55	47	55	62	70	88	104
Rahimabad	Balamao	15.0	19	23	28	39	49	35.0	39	43	46	53	60	50	58	66	74	92	109
Balamao	Hardoi	16.0	20	24	29	41	51	35.0	39	43	46	53	60	51	59	67	75	94	111
Hardoi	Rosa	16.0	20	24	29	41	51	35.0	39	43	46	53	60	51	59	67	75	94	111
Rosa	Shahjahanpur	16.0	20	25	30	42	52	41.0	46	50	54	62	71	57	66	74	84	104	123
Shahjahanpur	Bareilly	16.0	20	25	30	42	52	39.0	43	47	51	59	67	55	64	72	81	101	120
Bareilly	Rampur	16.5	21	25	31	42	53	35.0	39	43	46	53	60	52	60	68	76	96	114
Rampur	Moradabad	16.5	21	25	31	42	53	47.0	52	57	62	71	81	64	73	82	92	114	134
Moradabad	Najibabad	17.0	21	26	32	44	56	26.0	29	32	34	39	45	43	50	58	66	84	101
Najibabad	Muzzampur Narra	17.5	22	27	32	45	57	32.0	36	39	42	49	55	50	58	66	74	94	112
Muzzampur Narra	Laksar	17.5	22	27	32	45	57	28.0	31	34	37	42	48	46	53	61	69	88	105
Laksar	Khanampura	18.5	23	28	34	48	60	33.0	37	40	43	50	57	52	60	68	78	98	117
Khanampura	Saharanpur	21.3	26	32	38	52	65	25.0	28	30	33	38	43	46	54	62	71	90	108
Saharanpur	Jagadhari	13.5	17	20	24	32	40	30.5	34	37	40	46	53	44	51	57	64	79	93
Jagadhari	Ambala Cannt	12.7	16	19	23	31	39	30.8	34	37	40	47	53	44	50	56	63	78	92
Ambala City	Rajpura	31.0	39	47	56	77	97	53.0	59	64	69	80	91	84	98	111	126	158	188
Rajpura	Shirhind	23.0	29	35	43	60	76	44.0	49	53	58	67	76	67	78	89	101	127	152
Shirhind	Sanehwal	12.1	15	19	23	32	40	39.0	43	47	51	59	67	51	59	66	74	91	107
Sanehwal	Ludhiana	19.0	24	29	35	49	61	46.0	51	56	60	70	79	65	75	85	95	118	140

Source: JICA Study Team

Table 6-34 Projection of the Number of Trains on Western Corridor (North Route)

West Corridor North Route Average No. of Trains per day per direction

Section		Freight						Passenger						Total					
		2004-05	2011-12	2016-17	2021-22	2026-27	2031-32	2004-05	2011-12	2016-17	2021-22	2026-27	2031-32	2004-05	2011-12	2016-17	2021-22	2026-27	2031-32
Vadodara "D"	Bajuwa	18	36	47	60	77	94	46	53	57	62	71	82	64	88	105	122	148	176
Bajuwa	Vasad	18	37	50	63	81	100	46	53	57	62	71	82	64	90	107	125	153	182
Vasad	Anand	17	35	48	61	79	96	44	50	55	59	68	78	60	86	102	120	147	175
Anand	Kanjari Bori	24	45	61	76	96	117	49	56	61	66	76	87	72	102	122	142	172	204
Kanjari Bori	Nadiad	24	45	60	76	96	116	47	54	59	64	73	84	70	99	119	139	169	200
Nadiad	Geratpur	24	45	60	76	96	116	47	54	59	64	73	84	70	99	119	139	169	200
Geratpur	Vatva	23	44	59	75	95	115	46	53	58	63	72	83	69	98	117	137	167	198
Vatva	Kankaria	29	51	66	82	102	123	46	53	58	63	72	83	75	104	124	144	174	206
Kankaria	Ahmedabad	42	65	81	98	119	141	46	53	58	63	72	83	88	118	139	161	192	224
Ahmedabad	Sabarmati	24	46	61	77	98	118	40	46	50	55	63	72	64	93	112	132	160	190
Sabarmati	Chandlodia	23	47	63	80	101	122	40	46	50	55	63	72	63	94	114	134	163	194
Chandlodia	Khodiar	7	23	32	42	57	72	18	21	23	25	28	32	25	43	55	67	86	105
Khodiar	Mahesana	3	17	25	34	48	61	17	20	21	23	27	31	20	36	46	57	74	92
Mahesana	Palanpur	9	26	37	48	64	80	17	20	21	23	27	31	26	46	58	71	91	111
Palanpur	Abu Road	8	29	43	57	77	98	18	21	23	25	28	32	26	50	65	81	106	130
Abu Road	Marwar Jn.	10	32	46	60	81	102	17	20	21	23	27	31	27	52	67	83	108	133
Marwar Jn.	Beawar	8	29	42	56	76	97	12	14	15	16	19	22	20	43	57	72	95	118
Beawar	Dorai	8	30	43	57	77	98	13	15	16	18	20	23	21	45	59	74	98	121
Dorai	Madar	8	29	42	56	76	97	0	0	0	0	0	0	8	29	42	56	76	97
Madar	Phulera	8	29	42	56	76	96	13	15	16	18	20	23	21	44	58	73	96	120
Phulera	Jaipur	13	36	50	66	87	109	22	26	28	30	35	40	35	61	78	96	122	149
Jaipur	Bandikui	8	29	42	55	75	96	14	16	18	19	22	25	22	45	59	74	97	121
Bandikui	Alwar	8	29	42	56	76	96	14	16	18	19	22	25	22	45	60	75	98	121
Alwar	Rewari	9	31	45	59	80	100	14	16	18	19	22	25	23	47	62	78	102	126
Rewari	Delhi	9	28	41	54	72	90	15	17	19	20	24	27	24	46	60	74	96	118
Phulera	Ringus	0	0	0	0	0	0	5	6	6	7	8	9	5	6	6	7	8	9
Ringus	Rewari	6	10	13	16	24	32	6	7	8	8	9	11	12	17	20	24	33	43

Source :JICA Study Team

Table 6-35 Projection of the Number of Trains on Western Corridor (South Route)

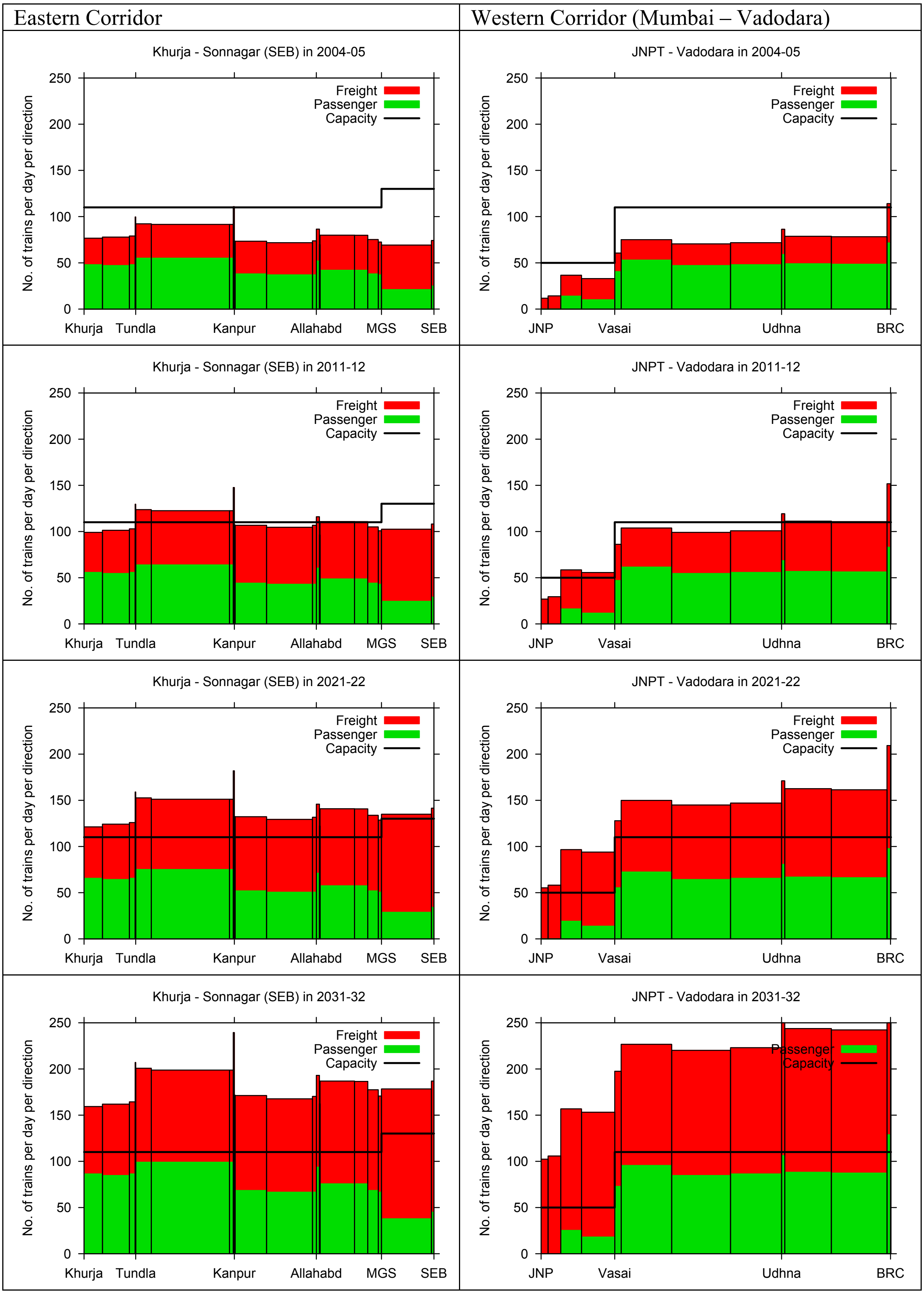
West Corridor Main Route Average No. of Trains per day per direction

Section		Freight						Passenger						Total					
		2004-05	2011-12	2016-17	2021-22	2026-27	2031-32	2004-05	2011-12	2016-17	2021-22	2026-27	2031-32	2004-05	2011-12	2016-17	2021-22	2026-27	2031-32
JNPort	Jasai	12	27	41	55	79	102	0	0	0	0	0	0	12	27	41	55	79	102
Jasai	Panvel	14	29	44	58	82	106	0	0	0	0	0	0	14	29	44	58	82	106
Panvel	Diva	23	42	60	78	105	132	14	16	18	19	22	25	37	59	77	97	126	157
Diva	Vasai Road	23	44	62	80	108	135	10	12	13	14	16	18	33	56	75	94	123	153
Vasai Road	Virar	20	39	56	72	98	125	41	47	51	55	64	73	61	86	107	128	162	197
Virar	Dahanu	22	42	60	77	104	131	53	61	67	72	83	95	75	104	127	150	187	227
Dahanu	Valsad	23	45	63	81	108	135	47	55	59	64	74	85	70	99	122	145	182	220
Valsad	Udhna	24	45	63	81	109	137	48	56	60	66	75	86	72	101	124	147	184	223
Udhna	Surat	27	51	71	90	120	149	59	68	74	81	93	106	86	119	145	171	212	255
Surat	Bharuch	30	54	75	96	126	156	49	57	62	67	77	88	79	111	137	163	202	244
Bharuch	Vadodara 'P'	30	54	75	95	125	155	49	56	61	66	76	87	78	110	136	161	201	242
Vadodara 'P'	Vadodara 'D'	43	69	90	112	143	174	72	83	90	98	112	129	114	152	180	209	255	303
Vadodara 'D'	Vadodara 'Z'	18	40	57	74	101	128	26	30	32	35	40	46	43	69	89	109	141	174

South Route

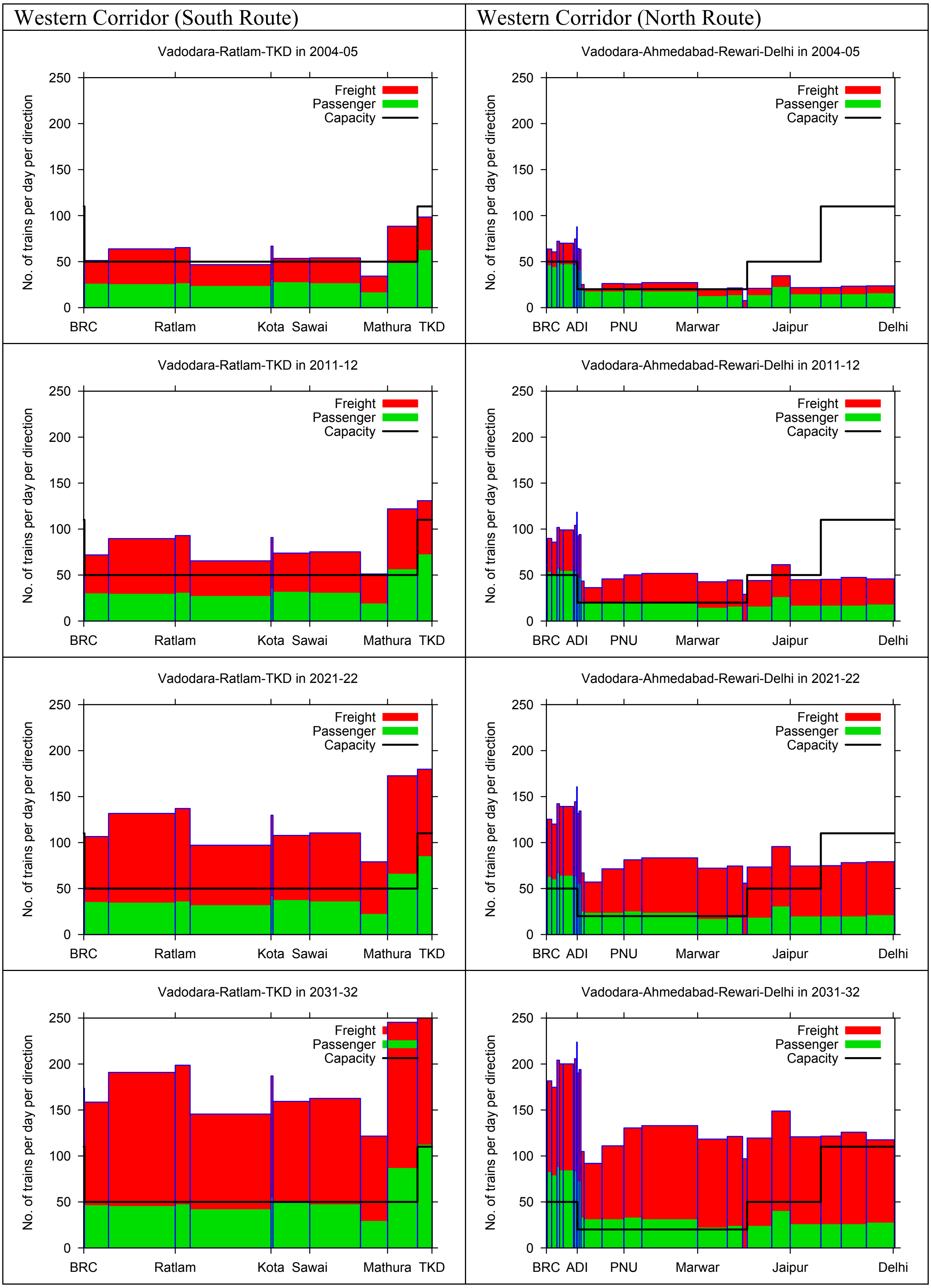
Section		Freight						Passenger						Total					
		2004-05	2011-12	2016-17	2021-22	2026-27	2031-32	2004-05	2011-12	2016-17	2021-22	2026-27	2031-32	2004-05	2011-12	2016-17	2021-22	2026-27	2031-32
Vadodara 'Z'	Godhra	26	42	57	72	92	113	26	30	32	35	40	46	51	72	89	107	132	159
Godhra	Ratlam	39	61	79	97	122	146	25	29	31	34	39	45	64	90	110	132	161	191
Ratlam	Nagda	39	63	82	102	127	152	26	30	33	36	41	47	65	93	115	137	167	199
Nagda	Kota	24	39	52	66	85	104	23	27	29	31	36	41	47	65	81	97	121	146
Kota	Gurla	37	56	72	89	111	133	30	35	38	41	47	54	67	91	110	130	158	187
Gurla	Sawai	26	42	57	71	91	111	27	31	34	37	42	49	53	74	91	108	133	159
Sawai	Bayana	28	45	60	75	95	116	26	30	33	36	41	47	54	75	93	110	136	163
Bayana	Mathura	18	33	45	57	75	93	16	19	20	22	25	29	34	51	65	79	100	122
Mathura	Palwal	40	66	87	107	133	159	48	56	60	66	75	86	88	122	147	173	208	245
Palwal	Tughlakabad	36	59	77	95	119	142	62	72	78	85	97	112	98	131	155	180	216	254

Source: JICA Study Team



Source: JICA Study Team

Figure 6-14 Future traffic flow of the Corridors



Source: JICA Study Team

Figure 6-14 Future traffic flow of the Corridors (cont')

6.6 DFC TRAFFIC FORECAST

6.6.1 Base Year DFC Traffic in PETS-I

Assuming that the DFC exists on the north route of the Western Corridor in year 2004-05, the quantity of goods that would be carried by the DFC was calculated in PETS-I based on O/D data in May 2004 as shown in Table 6-36 and Table 6-37. It was assumed that trains whose travel distance is less than 200 km would not use the DFC even if they use the north route of the Western Corridor. The number of trains was computed from the quantity of goods for both the current axle load capacity and 25 ton axle load capacity.

Table 6-36 Transport Volume by DFC in year 2004-05 (non-container)

Unit: million tonne /year

Commodity	Eastern Corridor			Western Corridor		
	Kurja → Sonnagar	Sonnagar → Kurja	Total	Dadri → JN. Port	J.N.Port → Dadri	Total
Coal	-	34.52	34.52	0.128	2.179	2.307
Iron/ Steel	-	4.64	4.64	-	0.491	0.491
POL	-	-	-	2.566	1.516	4.082
Fertilizer	1.46	-	1.46	1.067	0.793	1.860
Foodgrains	4.38	-	4.38	1.831	0.176	2.007
Cement	3.51	-	3.51	1.948	0.382	2.330
Limestone	3.13	-	3.13	-	-	-
Salt	1.14	-	1.14	0.666	1.586	2.252
Others	1.50	1.50	3.00	1.713	0.441	2.154
Total	15.21	40.66	55.87	9.920	7.564	17.483

Source: PETS-I

Table 6-37 Container Traffic Volume by DFC in 2004-05 (Western Corridor)

Dadri → JN.Port	J.N.Port → Dadri	Total
296,220 TEU	193,908 TEU	490,128 TEU

Source: PETS-I

6.6.2 Train Load

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.

Table 6-38 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
Note*: Assumption in this report

6.6.3 Projection of DFC on the Eastern Corridor

The section-wise and commodity-wise number of trains on the DFC was estimated by multiplying the numbers of trains during year 2004-05 by growth rates that were computed from the commodity-wise freight demand forecast of the corridors (Table 6-15). The number of trains with empty wagons returning after unloading was estimated from traffic growth of the opposite direction as:

The number of empty trains of the projection year in UP (DOWN) direction	=	The number of empty trains of the base year in UP (DOWN) direction	×	Growth Ratio of the number of trains (excl. empties) in DOWN (UP) direction from the base year to the projection year

The result of the projection for the Eastern Corridor was shown in Table 6-39.

Table 6-39 No. of Trains on the DFC (East), current axle load

Unit: No. of Trains

2011-12		Howrah -> Delhi							Delhi -> Howrah			
Coal	Iron&Steel	Others	Empties	Total	Section		Food grain	Fertilizers	Cement	Others	Empties	Total
43.5	5.1	2.8	5.6	56.9	Sonnagar	Mughalsara	4.0	2.0	1.6	7.1	35.1	49.9
40.7	5.1	2.8	7.7	56.3	Mughalsara	Allahabad	4.0	1.2	5.1	7.4	33.3	51.0
37.6	4.4	2.8	6.8	51.5	Allahabad	Kanpur	4.0	0.8		6.1	31.4	42.4
31.2	3.9	2.6	6.3	44.0	Kanpur	Tundla	3.8	0.9		6.1	23.8	34.6
28.1	3.5	2.6	4.7	38.9	Tundla	Khurja	3.3			2.8	22.9	29.0
6.6	0.8	1.3	3.5	12.1	Khurja	Ludhiana	6.8			0.2	6.3	13.3

2016-17		Howrah -> Delhi							Delhi -> Howrah			
Coal	Iron&Steel	Others	Empties	Total	Section		Food grain	Fertilizers	Cement	Others	Empties	Total
52.0	5.5	3.7	6.9	68.1	Sonnagar	Mughalsara	4.3	2.5	2.0	9.6	41.9	60.2
47.5	5.5	3.7	9.4	66.1	Mughalsara	Allahabad	4.3	1.5	6.2	9.4	39.0	60.4
42.2	4.8	3.7	8.0	58.7	Allahabad	Kanpur	4.3	1.0		7.6	35.6	48.5
35.8	4.0	3.4	7.4	50.7	Kanpur	Tundla	3.9	1.2		7.5	27.4	40.0
32.9	3.6	3.4	5.1	45.0	Tundla	Khurja	3.4			3.2	26.7	33.4
6.8	0.9	1.6	3.9	13.2	Khurja	Ludhiana	7.6			0.3	6.7	14.6

2021-22		Howrah -> Delhi							Delhi -> Howrah			
Coal	Iron&Steel	Others	Empties	Total	Section		Food grain	Fertilizers	Cement	Others	Empties	Total
57.8	6.0	5.0	8.7	77.5	Sonnagar	Mughalsara	4.5	3.1	2.4	13.0	47.0	70.1
52.1	6.0	5.0	11.3	74.4	Mughalsara	Allahabad	4.5	1.9	7.5	12.0	43.3	69.2
45.3	5.1	5.0	9.4	64.9	Allahabad	Kanpur	4.5	1.3		9.4	39.0	54.2
38.9	4.1	4.4	8.7	56.2	Kanpur	Tundla	4.1	1.5		9.2	30.0	44.8
36.0	3.7	4.4	5.5	49.7	Tundla	Khurja	3.6			3.6	29.6	36.7
7.1	1.0	2.0	4.4	14.6	Khurja	Ludhiana	8.5			0.4	7.2	16.1

2026-27		Howrah -> Delhi							Delhi -> Howrah			
Coal	Iron&Steel	Others	Empties	Total	Section		Food grain	Fertilizers	Cement	Others	Empties	Total
64.2	6.2	5.4	9.1	84.8	Sonnagar	Mughalsara	4.6	3.2	2.5	13.8	51.8	75.9
57.1	6.2	5.4	11.9	80.5	Mughalsara	Allahabad	4.6	1.9	7.8	12.8	47.1	74.2
48.5	5.3	5.4	9.8	69.0	Allahabad	Kanpur	4.6	1.3		10.0	41.6	57.5
42.3	4.3	4.7	9.1	60.4	Kanpur	Tundla	4.2	1.5		9.8	32.4	47.9
39.5	3.8	4.7	5.8	53.8	Tundla	Khurja	3.7			3.9	32.1	39.7
7.4	1.2	2.5	5.0	16.1	Khurja	Ludhiana	9.5			0.5	7.8	17.8

2031-32		Howrah -> Delhi							Delhi -> Howrah			
Coal	Iron&Steel	Others	Empties	Total	Section		Food grain	Fertilizers	Cement	Others	Empties	Total
71.4	8.4	9.2	13.8	102.8	Sonnagar	Mughalsara	5.4	3.8	3.6	23.8	60.9	97.5
62.5	8.4	9.2	17.1	97.3	Mughalsara	Allahabad	5.4	2.3	11.5	19.9	55.0	94.1
52.0	7.3	9.2	13.5	82.0	Allahabad	Kanpur	5.4	1.6		14.9	48.2	70.0
45.9	5.8	8.1	12.6	72.5	Kanpur	Tundla	4.8	1.8		14.8	37.9	59.4
43.2	5.2	8.1	6.8	63.4	Tundla	Khurja	4.2			4.6	37.9	46.7
7.8	1.4	3.2	5.7	18.0	Khurja	Ludhiana	10.7			0.7	8.5	19.9

Source: JICA Study Team

6.6.4 Projection of DFC on the Western Corridor

For the Western Corridor, Only the case of the DFC on the north route was analysed because the south route would not be able to catch traffic which relates to ports in Gujarat. It was assumed that the all container traffic along the corridors projected in Table 6-16 would divert to the DFC, while 95% of container traffic on the south route would divert. The diversion rate was estimated from the train O/D. On the other hand, it was assumed that only 40% of non-container traffic would divert from the south route to the DFC, based on that non-container traffic between Delhi area and the south area of Vadodara was estimated to be 4 trains per day at the present from the train O/D. Based on this, the number of container traffic on the DFC was computed by allocating traffic of north and south route.

The non-container traffic was projected using the growth ratios in Table 6-15. The result of the projection is shown in Table 6-40.

Table 6-40 Projection of the Number of DFC Trains on the Western Corridor

Unit: No. of Trains per direction

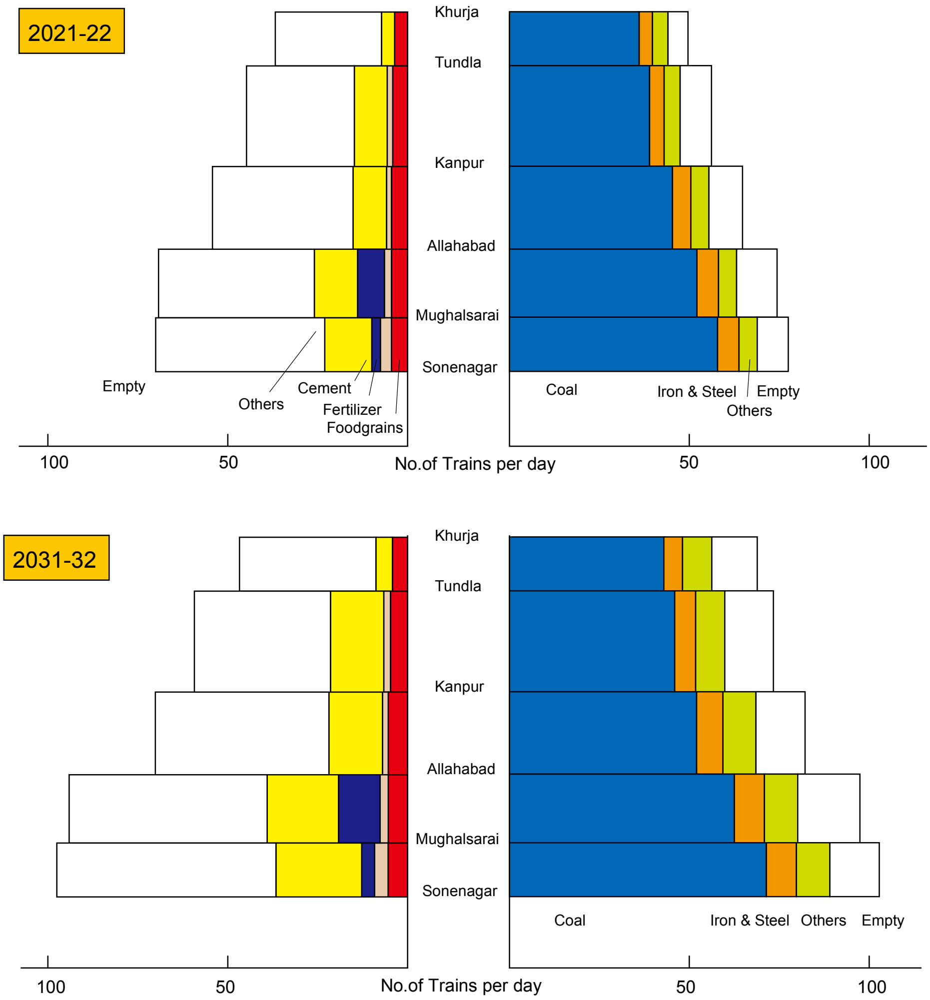
Section	2011-12			2016-17		
	Non-Container	Container	Total	Non-Container	Container	Total
J.N.Port – Vasai Road	5	28	33	6	44	50
Vasai Road – Surat	6	28	34	7	44	51
Surat – Vadodara	9	28	37	11	44	55
Vadodara – Ahmedabad	25	32	57	31	50	81
Ahmedabad – Palanpur	14	32	46	17	50	67
Palanpur – Marwar	14	38	52	17	60	77
Marwar – Phulera	13	37	50	16	59	75
Phulera – Rewari	12	37	49	15	59	74
Rewari – Phthala	14	34	48	18	55	73
Phthala – Dadri	14	34	48	18	55	73

Section	2021-22			2031-32		
	Non-Container	Container	Total	Non-Container	Container	Total
J.N.Port – Vasai Road	8	50	58	10	95	105
Vasai Road – Surat	9	50	59	12	95	107
Surat – Vadodara	13	50	63	18	95	113
Vadodara – Ahmedabad	37	57	94	49	109	148
Ahmedabad – Palanpur	21	57	78	28	109	137
Palanpur – Marwar	20	68	88	27	130	157
Marwar – Phulera	19	67	86	25	128	153
Phulera – Rewari	18	67	85	25	128	153
Rewari – Phthala	21	62	83	29	119	148
Phthala – Dadri	21	62	83	29	119	148

Note: 90 TEU per train
Source: PETS-I JICA Study Team

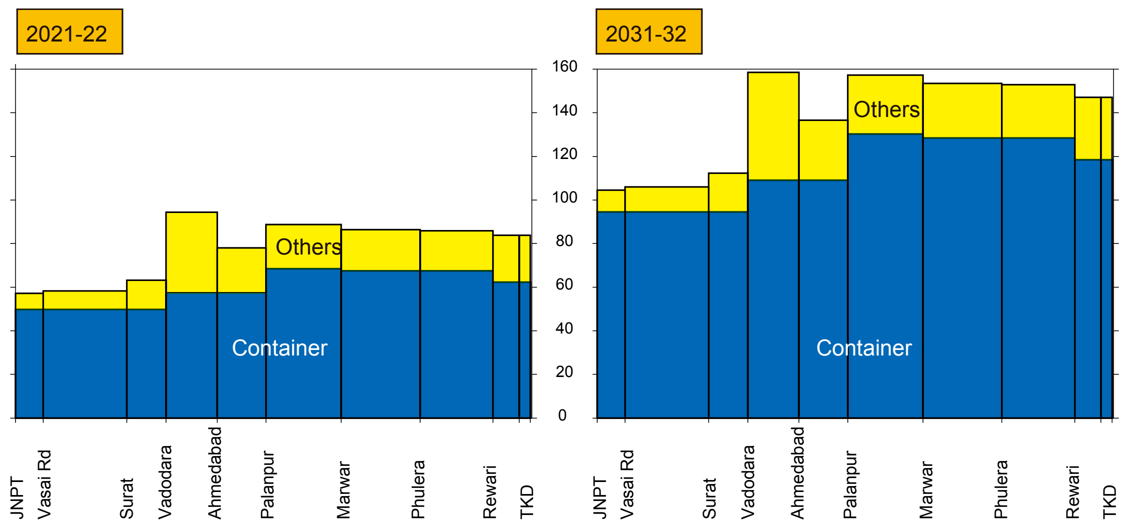
The above-projection is the mixture of PETS-I and the analysis by the JICA Study Team, because the projection shown in Table 6-39 and Table 6-40 was based on the traffic assignment in PETS-I which reflected the present pattern of railway transport in India, while traffic growth rates and the container traffic were taken from the projections in this Study.

Section-wise traffic volume (2021-22 and 2031-32) on the DFC for the Eastern Corridor and the Western Corridor is illustrated in Figure 6-15 and Figure 6-16.



Source: JICA Study Team

Figure 6-15 Section-wise traffic volume on the DFC (East), current axle load



Source: JICA Study Team

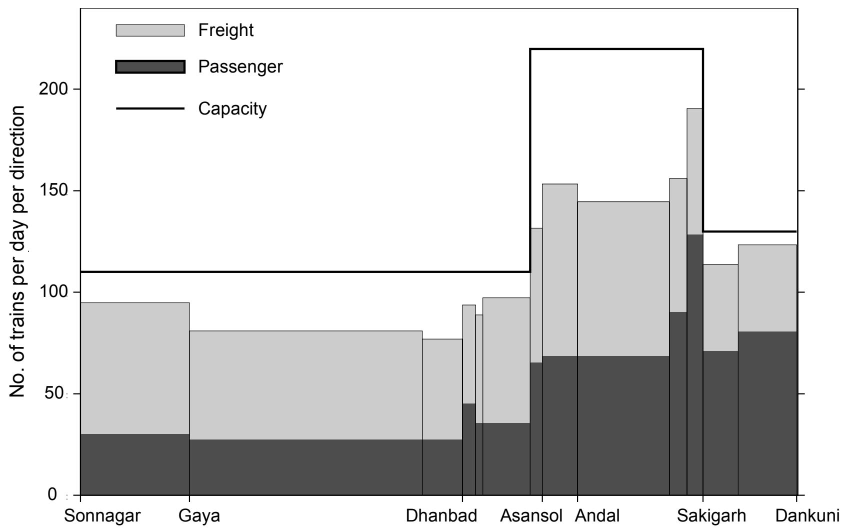
Figure 6-16 Section-wise Traffic Volume on the DFC (West), current axle load

6.7 TRAFFIC DEMAND ON HOWRAH - SONNAGAR

As well as PETS-II, This study focuses on Ludhiana – Khurja and Delhi – Sonnager segments for the Eastern Corridor. Only a demand-capacity analysis was carried out.

The major commodity of the Eastern Corridor is coal, which enters the main route at Sonnagar and stations near Dhanbad from coal fields and goes to the direction of Delhi. Therefore, the traffic volume of coal between Sonnagar and Dhanbad is smaller than that of Delhi – Sonnagar section. Although various commodities are carried by rail between Dhanbad and Howrah, there is no dominant commodity like coal between Delhi and Sonnagar. There is a plan to develop Sagar port near Kolkata as an international container port, which will generate transport demand of container by rail if it is implemented. However, since the plan does not so much take shape, container transport in the Eastern Corridor was not taken into consideration for the demand-capacity analysis.

Figure 6-17 illustrates the comparison between line capacity and traffic demand in 2021-22 for Sonnagar - Dankuni section. Since inter-city passenger traffic is the major and the traffic characteristics are different from other sections, the section between Dankuni and Howrah was excluded. The chart shows that there will be enough capacity on this section up to 2021-22. Although it was estimated that this section would be saturated by 2031-32, it is not necessary to consider the saturation because it will happen 20 years after commencement of the DFC project.



Source: JICA Study Team
Note: Dankuni- Howrah section is excluded

Figure 6-17 Demand-Capacity Analysis on Sonnagar - Howrah

CHAPTER 7
ESTIMATION OF LINE CAPACITY

CHAPTER 7 ESTIMATION OF LINE CAPACITY

7.1 THE NEED FOR ESTIMATING

(1) An estimate of the line capacity that assumes the use of automatic signals is needed

At the present time, nearly all signal systems on Indian Railways are Absolute Block Signals. With this system, only one train at a time can be operated between stations. When examining the alternatives, there is a need to assume that an automatic signal system will be used to increase the number of trains to be operated.

(2) Indian Railways operates heavy trains, so experience figures from Japan may not be suitable as a reference

Indian Railways operates many trains that are each hauling more than 4,000 tonne, which is much heavier than trains in Japan. Therefore it is impossible to measure or estimate the number of trains that could be operated by using only the Japanese experience figures.

(3) There is a need to verify the line capacity statements of the sections of Indian Railways with automatic signals

There are sections of Indian Railways that are being converted to automatic signaling or under construction. The installation of automatic signals between Vadodara-Ahmedabad has already been completed and it has a line capacity of 85 trains (without a maintenance block, See Table 7-1). However, the increased amount is quite a bit lower than for similar undertakings in Japan. Therefore, it is clear that the figures from these examples cannot be used "as is" when evaluating alternative plans.

Table 7-1 Line Capacity of Indian Railways

	Double Track Line		Single Track Line	
Maintenance Block	Without	With	Without	With
Sections with absolute block system	65	54	24	20
Sections with automatic signaling system	85	71	-	-

Source: Line capacity statement 2004-05 Western Railway

It was with this background that estimates of line capacity with automatic signals were made in this study.

7.2 METHODS USED FOR ESTIMATING LINE CAPACITY

The following Figure 7-1 shows the methods used for estimating line capacity. Details are provided below.

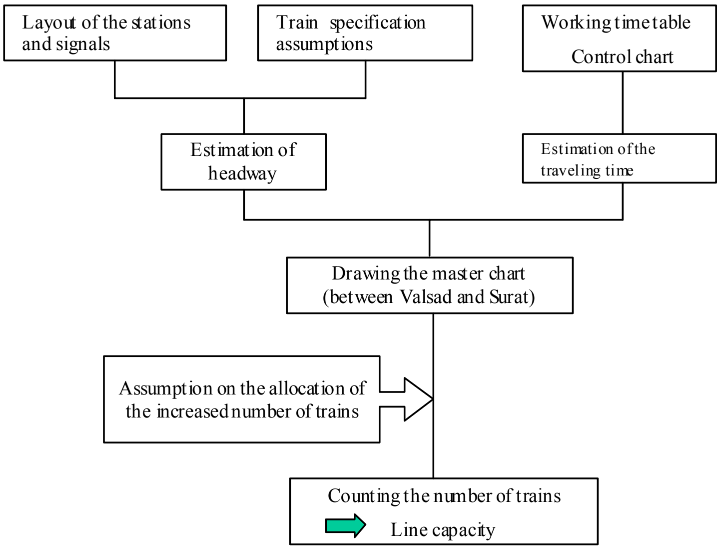


Figure 7-1 Method for Confirming the Improvement of Line Capacity

7.2.1 Estimations based on a model section

In this investigation, the line capacity is estimated by the charted line capacity method that is widely used in India.

At first, a model section is selected. The section between Valsad-Surat (68.4 km) was selected because the operations in this section have been examined in this study. Then the chart for this section was drawn and the line capacity was calculated from the number of trains on this chart.

7.3 ASSUMPTIONS

7.3.1 Enhanced speed restrictions at turnouts

On Indian Railway lines, the speed for passing through a turnout is set at either 15 km/h or 30 km/h. This can be a major impediment in shortening headway. In this investigation, the speed for passing through a turnout was set at 45 km/h.

7.3.2 Improved loops at stations

It is assumed that stations will have a loop or loops so that trains in a continuous series can arrive and depart at stations one after another. This precondition eliminates the harshest impediment to headway – having trains in a continuous series arriving and departing on the same track.

7.3.3 Improved layout of the stations and the signals around the station

The allocation of signals when automatic signals are adopted is shown in Figure 7-2. Note that initially we had assumed that the displays for the blocking signals would be G-Y-R. However, the signal display system was changed to G-YY-Y-R because of the brake distance required for high-speed trains and the signal visibility distance. So the distance between block signals that had been 2.0 km initially was later changed to 1.5 km and the distance between signals near the station was reduced to 1.0km.

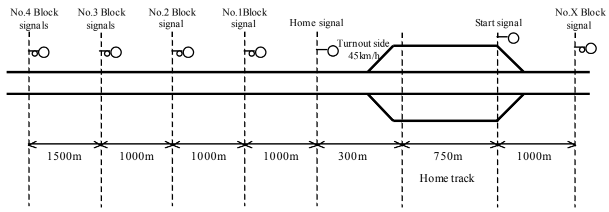


Figure 7-2 Layout of Stations and Signals Near Them

7.3.4 Confirmed locomotive performance and train specifications

Train lengths and some other dimensions were compiled in table form and are presented in Table 7-2 below.

Table 7-2 Profile of Trains

	Passenger Trains		Freight Trains	
	Special Trains	Others	Container Trains	Wagon Trains
Maximum Speed	120 km/h	100 km/h	100 km/h	75 km/h
Train Length	555m	555 m	647 m	651 m
Weight of the Train (including that of locomotive)	1320 t	1320 t	2200t	4840 t
Traction Power	4500 kW	4500 kW	4500 kW	4500 kW
Free Running Time Before Rise of Brakes	11 seconds	11 seconds	15 seconds	28 seconds
Deceleration Ratio	1.2 km/h/s	1.0 km/h/s	1.0 km/h/s	0.7 km/h/s

Source; JST

To confirm the performance of the existing trains, a survey on the cabin of the container train (with a haulage weight of 2,035 tons) was done between Vasai Road - Surat. The results of this survey are shown in Figure 7-3 and Figure 7-4.

1) The acceleration ratio of this train was estimated at over 0.33 km/h/s at the speed of 0-65 km/h.

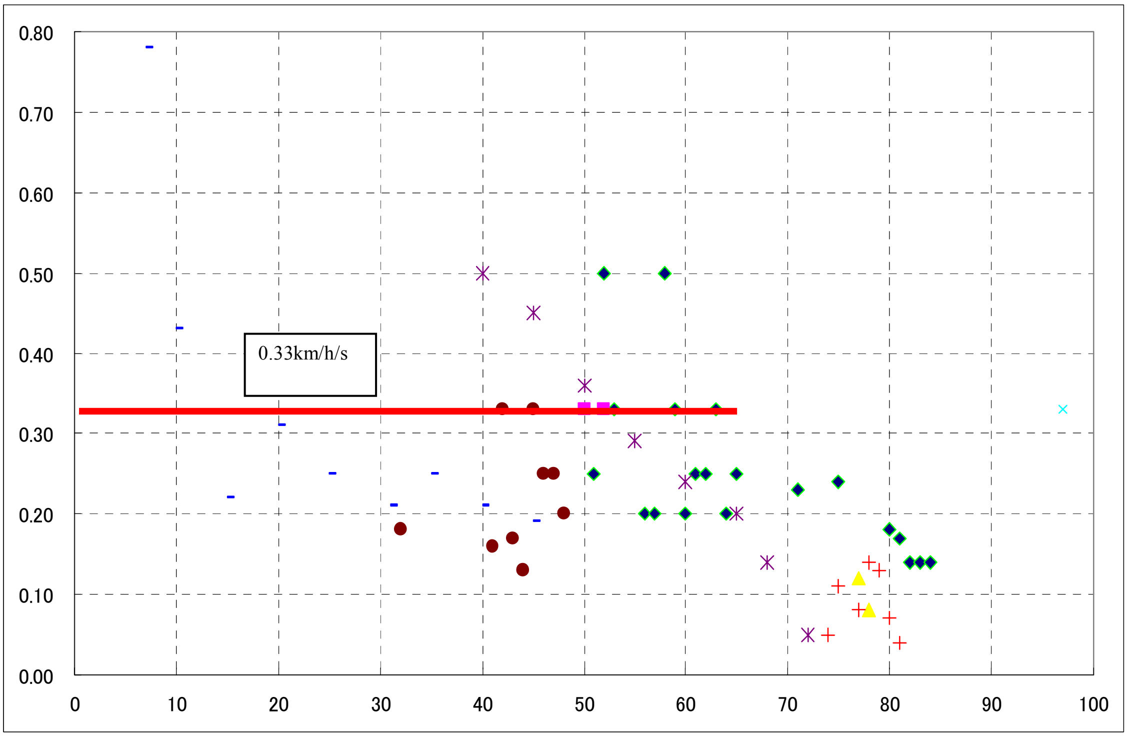
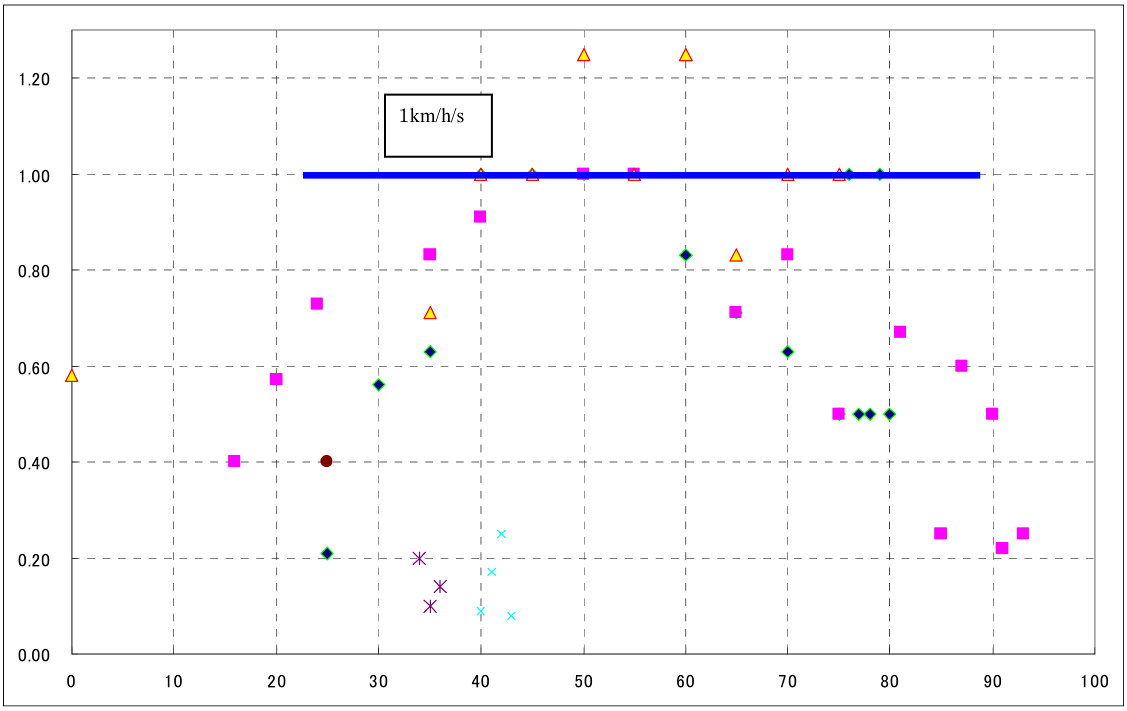


Figure 7-3 Distribution Chart of Acceleration

2) Its maximum speed was 85-90 km/h at a level section even though the "official" maximum speed of this train is 100 km/h.



Note) The deceleration ratio of this train was estimated at over 1km/h/s.

Figure 7-4 Distribution Chart of Deceleration

7.3.5 The brake performance of hauled coaches or wagons

We assumed that both passenger and freight trains are equipped with automatic brakes. In addition, it was assumed that both passenger and freight wagons are equipped with a brake system that enables the stopping brakes to be applied even if the brakes were released temporarily below a preset speed after the train driver/engineer had applied the brakes.

7.3.6 The allocations of the increased number of trains by train type

More trains can be operated by using automatic signals than by using Absolute Blocking Signals (ABS). Officials of Indian Railways indicated that one of the reasons for the low line capacity was because of the interference caused by the different speeds of the trains. This means that if the number of trains of a type is increased, it can dramatically affect the increase in line capacity. The preconditions for this investigation are shown in Table 7-3.

Table 7-3 Allocation of the Increased Number of Trains

Train type		Number of trains on the master chart	Number of trains on the new master chart based on the preconditions
120 km/h passenger train		3	Same as at present
100 km/h express or mail train		36	Increased the number as much as we can
100 km/h container train		10	
Stopping passenger train		8	Same as at present
75 km/h freight train		12	More than 20% of this category shall be increased
Total	Passenger	47	
	Freight	22	
	Total	69	

7.4 ESTIMATING LINE CAPACITY

7.4.1 Estimation of Headways

The headways were calculated based on the assumptions presented above. The results are shown in Table 7-4. Additionally, the relationship among the trains is shown in Figure 7-5.

Table 7-4 Calculated Headways

Unit:seconds

Case	Train type of the succeeding train	Special express	Mail/Express* Container trains	Freight trains
	Maximum speed	120 km/h	100 km/h	75 km/h
Succeeding train arrives at the station after the departure of the preceding train (A)		-	360.6	635.5
Succeeding train passes through after the passing of train of same type (B)		256.6	216.0	388.5
Succeeding train passes through after the arrival of the preceding train (C)		242.0	212.8	189.8
Succeeding train leaves the station after the passing through of the preceding train (D)		68.7	84.5	110.5

* The performance of the mail/express is better than that of the container trains, but here the figures for the container trains are adopted also for mail/express. This is because they are similar and it is safer to adopt the better values.

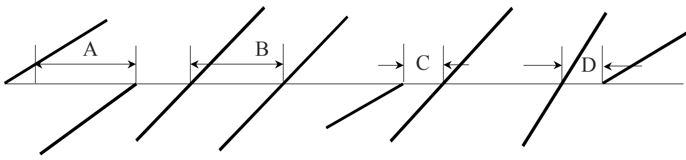


Figure 7-5 Figures of Headway Patterns

7.4.2 Estimation of travel time

Travel time between stations is needed for drawing the actual train chart for a section with automatic signals. The travel time was calculated by using the booked speed (i.e., 90% of the maximum speed) and adding deceleration/acceleration time for stopping. (Refer to Table 7-5)

Table 7-5 Additional Time for Stopping

	Arrival	Departure	Remarks
Passenger train	1.0 mimute	2.0 minute	Working time table of WR
Freight train	1.5 minute	3.5 minute	Calculated by study team

7.4.3 Drawing of the train charts

The down train chart for the section between Valsad and Surat was drawn based on the headways shown in Table 7-4. The results are shown in Figure 7-6 through Figure 7-11.

7.4.4 Calculation of the line capacity

The number of trains calculated from the charts is the line capacity without a maintenance block. And the line capacity with maintenance block can be obtained by multiplying the maintenance block ratio to the line capacity. The number of trains of the calculated line capacity with a maintenance block is shown in Table 7-6.

Table 7-6 Results of Line Capacity Calculations

Section Valsad to Surat		Current number of trains	Number of trains after automatic signals are installed	Increase/Decrease
		According to 3 July 2006 Control Chart (WR)	According to train chart created by study team	
Passenger	Super Express Trains	3	3	0
	Express Trains	36	85	49
	Local Trains	8	8	0
Freight	Container Trains	10	27	17
	General Freight Trains	12	17	5
Total		69	140	71

7.4.5 Remarks

IR presents that the line capacity for double track sections with automatic signals with a maintenance block will be 71 trains/direction (See Table 7-1). The results of our study show a 50% increase in line capacity over these IR figures.

The difference in these figures is thought to be because of the following circumstances.

1) The Indian statements do not include the assumption that yards will be improved.

2) The allocation of the signals is not aimed at optimizing line capacity.
3) The running performance of rolling stock is not as same as officially announced.
4) There are sections where the voltage of contact wire was dropped to lower level that that did not enable the locomotive to reach its full performance potential.
5) The methods used for train control are not suitable for high-density operation.

   The speed of the trains is reduced too far away from the stopping point to enable high-density operation.
6) There may be specific local information that we are not aware of.

7.4.6 Estimated line capacity of DFC and existing line after comprehensive improvements

Based on the above assumptions and information, the line capacity of DFC and that of the existing line after the comprehensive improvements are estimated.

1) DFC (Double-track section)

   The line capacity of DFC can be as high as that of that attained in Japan because the DFC will be constructed with the state-of-the-art technology and the rolling stock on it will be capable of high performance.

2) DFC (Single-track section)

   On the single track sections of DFC, crossing stations will be located every 10 km. An automatic signal system will not be introduced because this type of signal system is usually adopted on the section where continuous train operation is required. Continuous train operation is carried out rarely on single-track sections. . The scheduled speed of trains can be enhanced from 20 km/h (*IR Annual Statistical Statement 2004-05*) to 40 km/h because DFC will be constructed with modern technology and rolling stock running on it will have high performance. Based on these figures, the line capacity of DFC on a single-track section will be calculated as follows.

   The number of trains per direction to be operated for 20 hours a day = 20 hours X 60 minutes/(10 km/40 km/h/60minute)/2 = 40 trains

   Accordingly, our calculations show that the line capacity on a single-track section of DFC will be 40 trains/direction/day.

3) Existing lines (Double-track section with automatic signals)

   On the double-track section, which has received not only the introduction of the automatic signal system but also comprehensive improvement, line capacity can exceed the current line capacity.

   But in reality, many trains are operated on the existing line every day and it seems to be difficult to completely improve the line without stopping train operation. So the line capacity of the existing line after the comprehensive improvement is estimated to be a figure somewhere between that of the DFC and that of an IR double-track section with an automatic signal system.

   The line capacity with the comprehensive improvements = (140 + 71)/2 ≒ 110 trains/direction WMB

The line capacity of DFC and the existing line after the comprehensive improvements are shown in Table 7-7.

Table 7-7 Line capacity of DFC and existing line after the comprehensive improvements

Section	Signal system	DFC	Existing line	
			Comprehensive improvements	ABS (for reference)
Single-line	ABS	40	-	20
Doubleline	ABS	-	-	54
	Automatic signal	140	110	-
Triple line (Double line + Single line)	ABS	-	-	74
	Automatic signal +ABS	180	130	-

Source; JST

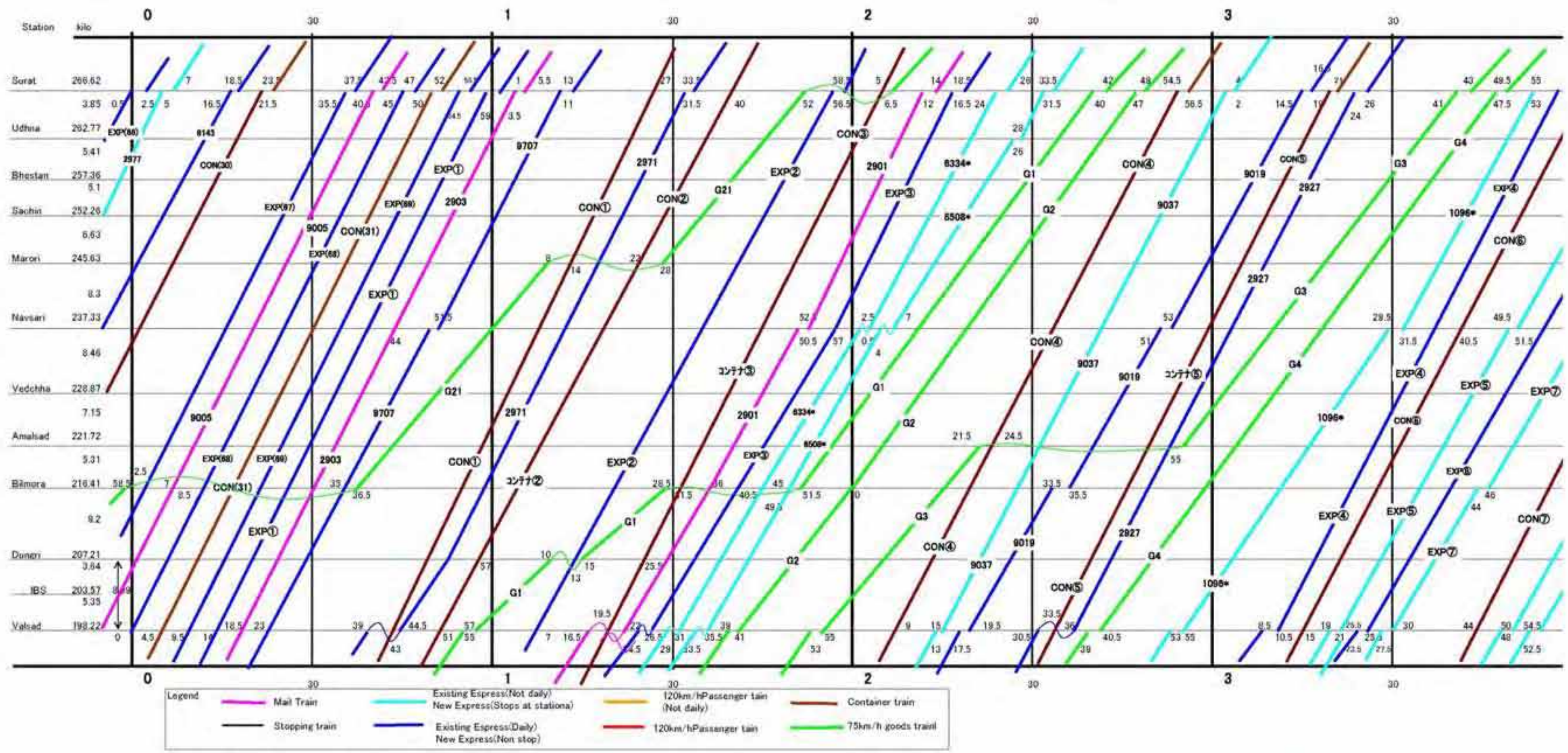


Figure 7-6 Train Chart for the Section between Valsad and Surat (1) 00:00 – 04:00

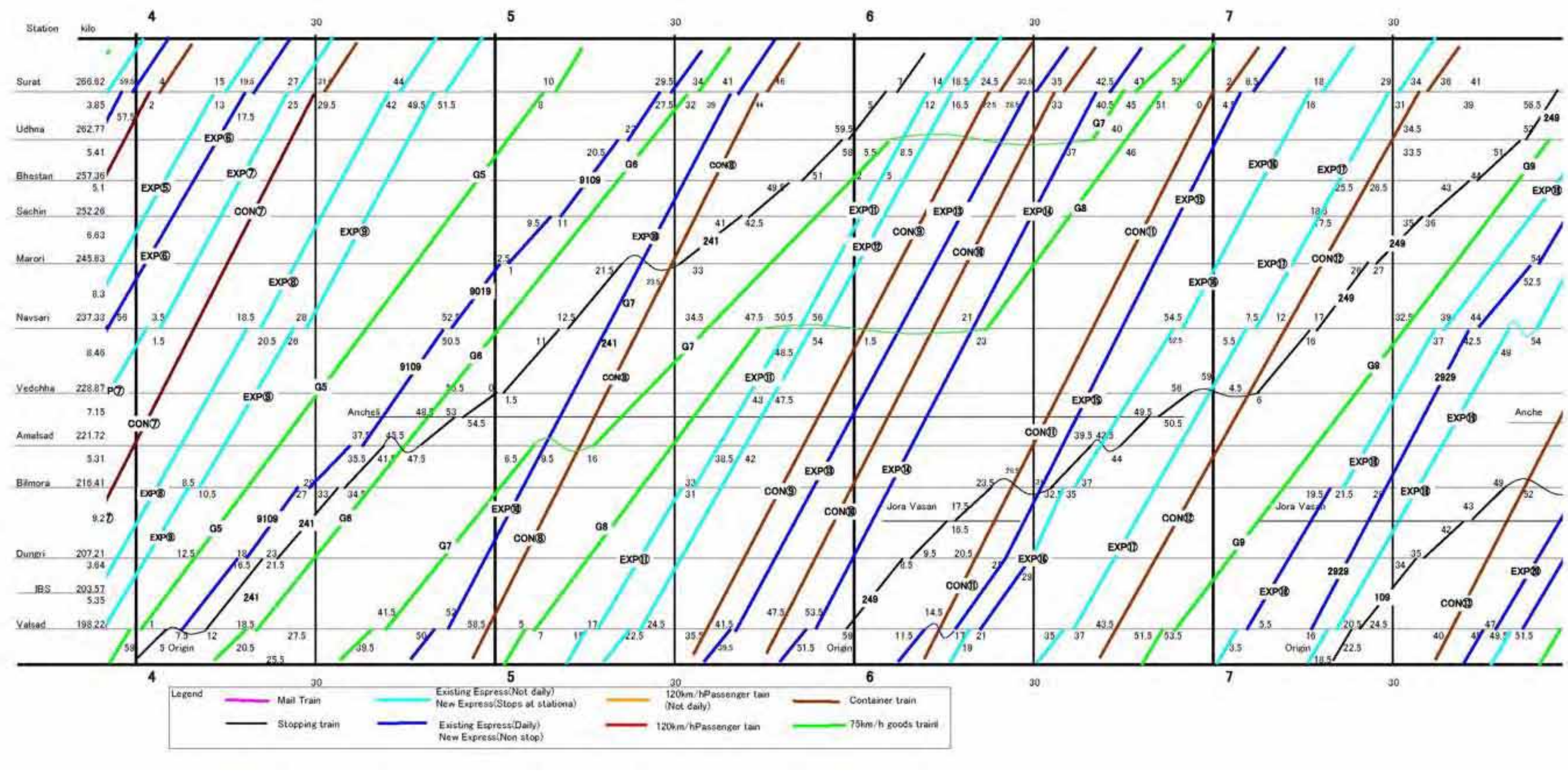


Figure 7-7 Train Chart for the Section between Valsad and Surat (2) 04:00 – 08:00

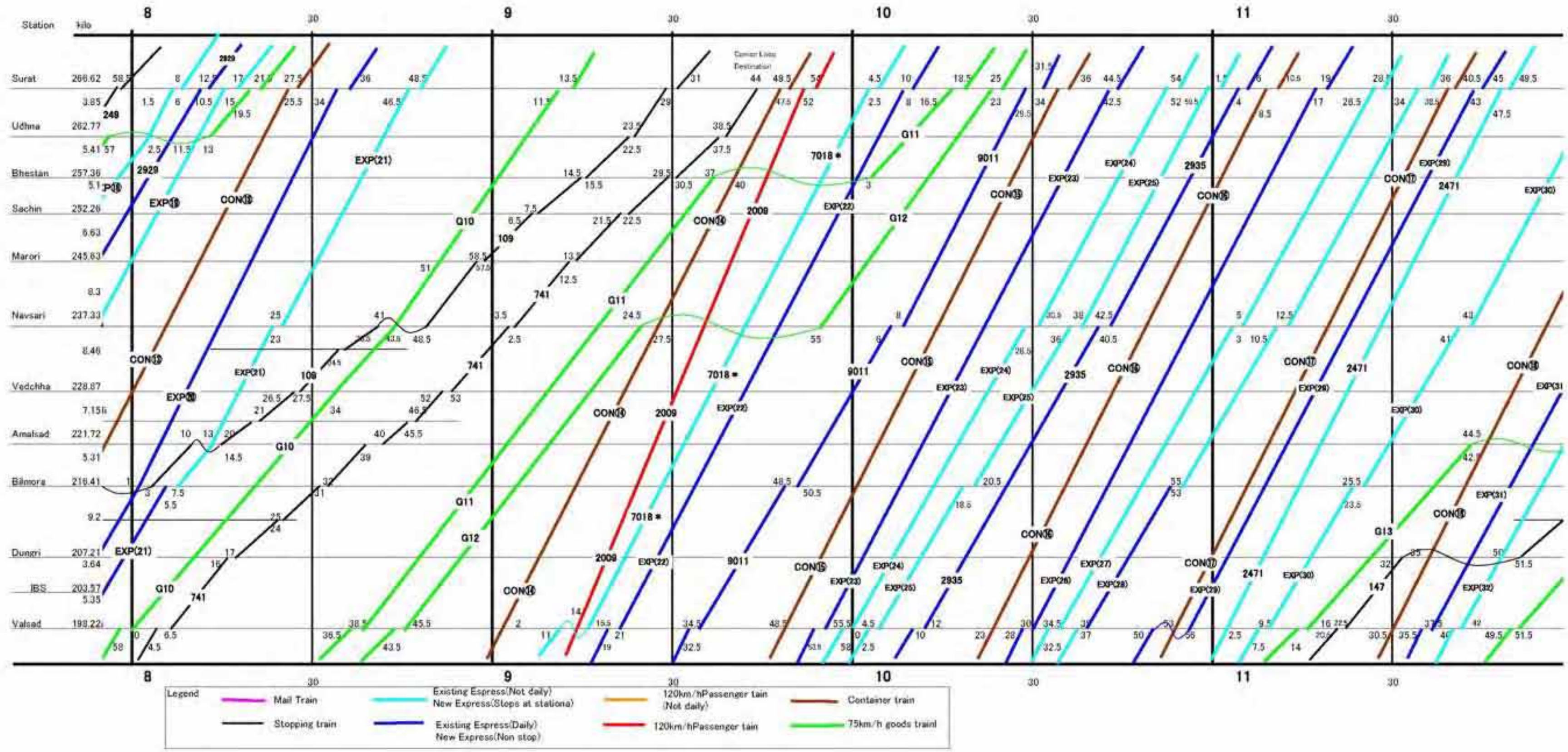


Figure 7-8 Train Chart for the Section between Valsad and Surat (3) 08:00 – 12:00

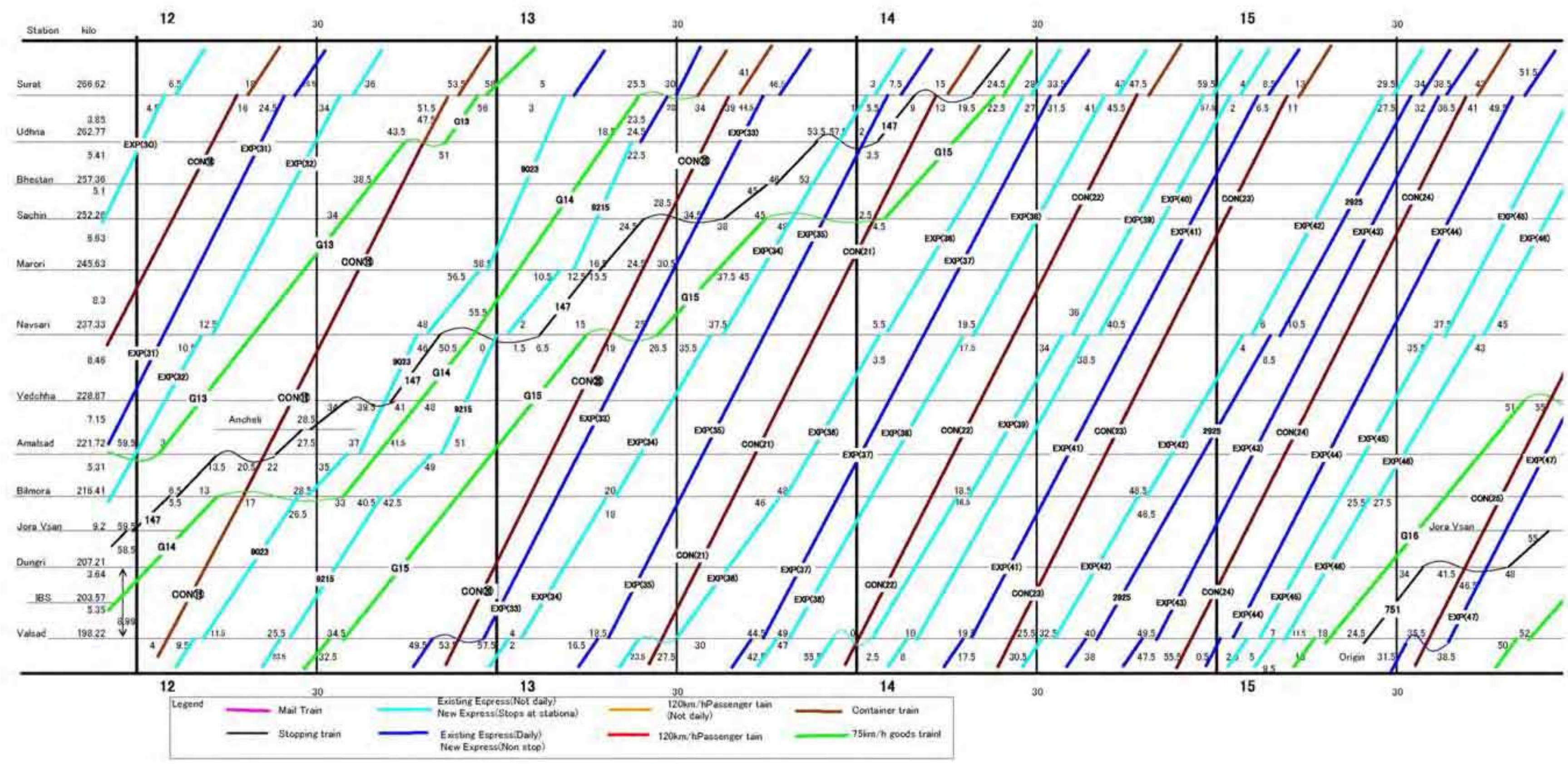


Figure 7-9 Train Chart for the Section between Valsad and Surat (4) 12:00 – 16:00

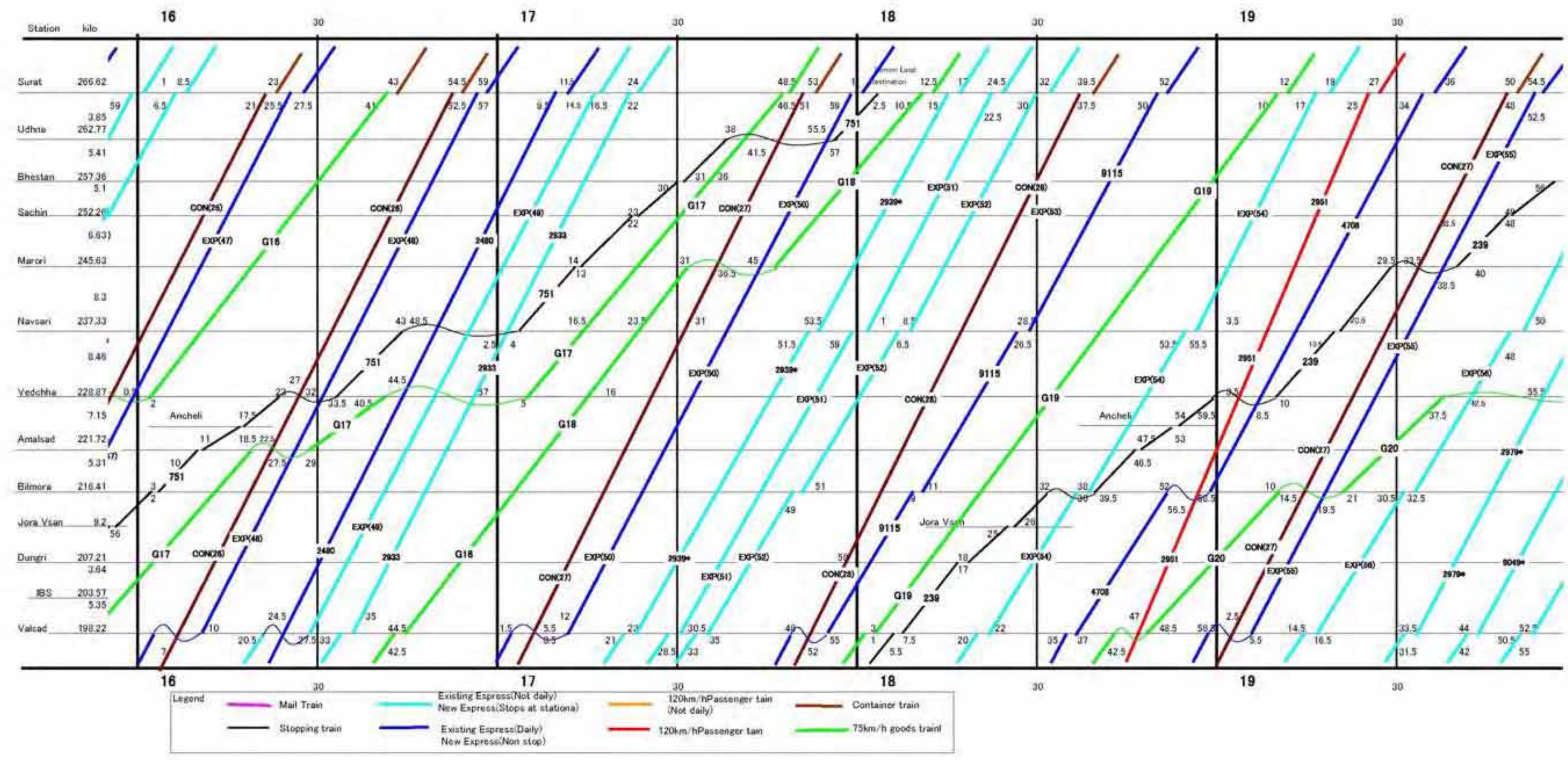


Figure 7-10 Train Chart for the Section between Valsad and Surat (5) 16:00 – 20:00

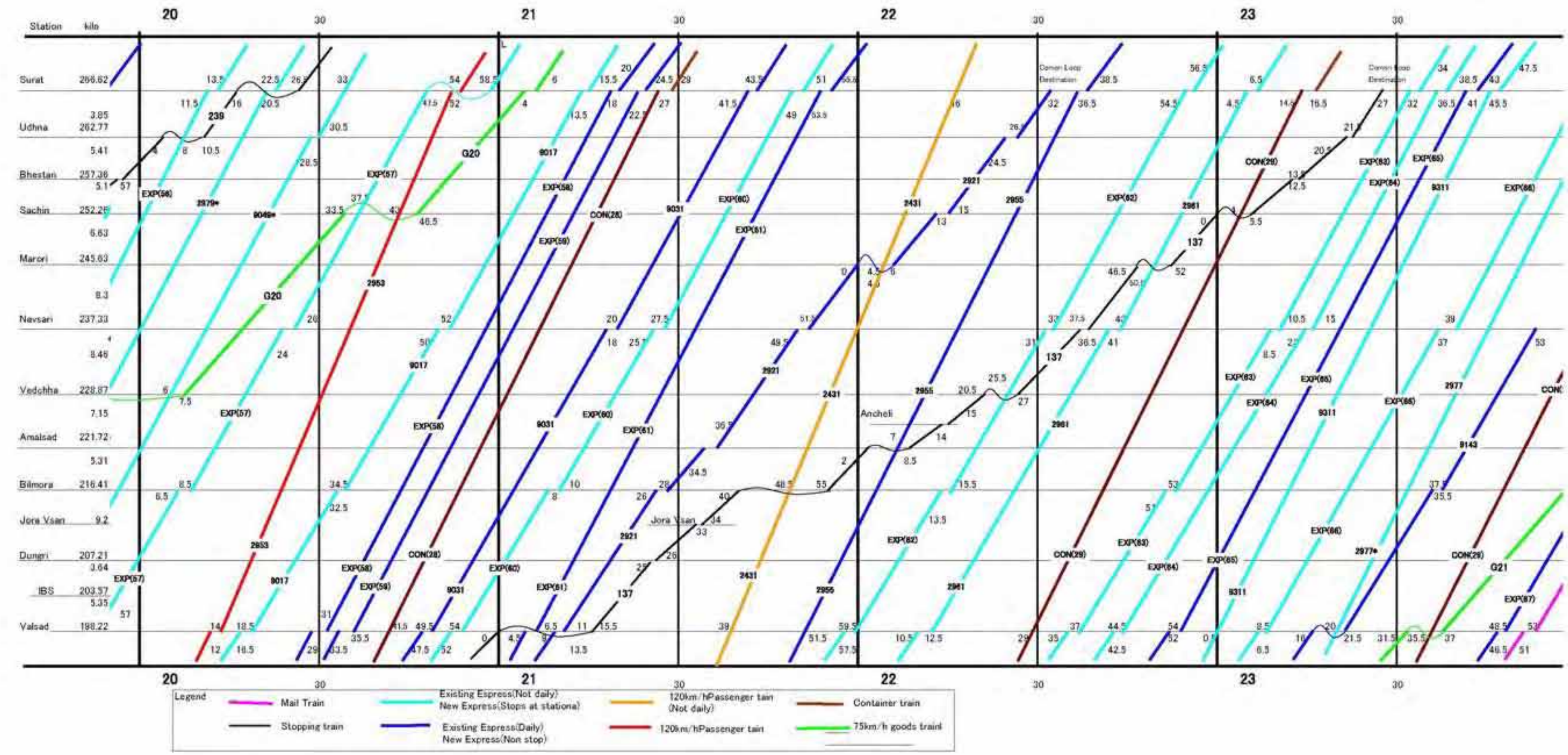


Figure 7-11 Train Chart for the Section between Valsad and Surat (6) 20:00 – 24:00

CHAPTER 8
THE MOST SUITABLE TECHNICAL OPTION

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8.1 REALIZATION OF EFFECTIVE LOGISTICS

All freight transport traditionally is intermodal transport except for trucks, because trucks handle both pickup and delivery of freight at origins and destinations. In recent years, India has been increasing its export and import, the demand of the interaction between roads and maritime and rail has consequently increased.

The challenge now is to improve the efficiency of the combined transport system. A systematic approach will be introduced as solutions to realize an efficient logistic system. Subsequently, new technologies and institutional systems have to be introduced.

8.1.1 Seamless Transport Systems

It is recognized the importance of transport treated as a single system for the improvement of the combined transport system. Single systems to be efficient require seamless transit between transport modes and facilities.

Comprehensive transport system is viewed from two perspectives; its structure and its performance. At these viewpoints, important issues on the transport system are easily recognized. In addition, an approach to reduce time and cost in the intermodal transport will be undertaken as one of the main theme of DFC planning.

(1) Comprehensive Transport System Structure (Hardware Approach)

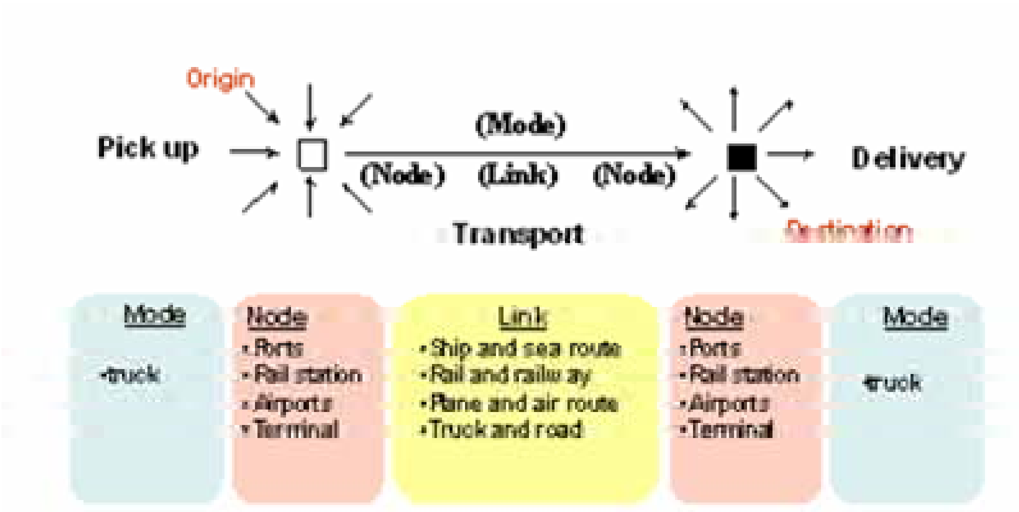


Figure 8-1 The Structure of Transport System

The structure of a transport system consists of links, nodes and modes. Links connects logistics activities, and refers to railway, road, waterway, airway, and in some cases pipelines. Nodes are cargo handling facilities like railway freight stations, truck terminals, ports and airports. Modes are transport vehicles which use the links, i.e. locomotives or freight wagons on railways, trucks on roads, ships on the waterways and airplanes on air route.

Throughput capacity from origin to destination is dependent on the capacity of each of the element of the transport system structure. Improvement of one link (a way) or one mode (a transport vehicle) would not bring capacity improvement of a whole transport system. Even with the capacity improvement of all links and all modes, the whole capacity of the system would not be progressed unless node capacity is improved as well. This is because the node connects transport vehicles to the facilities where unloading and loading activities are performed. Without node improvement, as in that case, congestion will occur at the node. It implies that capacity improvements should consider the transport elements as a whole based on the structure.

(2) Comprehensive Transport System Performance (Software Approach)

The second perspective of the comprehensive transport system improvement is viewed based on performance. Performance evaluation could be done at two levels: operations (i.e. transport planning and transport capacities) and controls (i.e. transport managements).

Transport system has many logistics facilities and activities. Evaluation of performance could be simplified by total transit time from the first origin facility to the last facility. It is therefore essential to consider the importance of the transit time for each mode and each node including the loading/unloading time. It implies that shortening transport time on one mode does not guarantee an overall total transit time improvement unless improvement of other times on other modes and nodes are made. In addition, if one mode has unpredictable transit time then total transit time can not be identified. All transit time and loading/unloading time are essentially required from modes and nodes for performance evaluation.

(3) Intermodal Transport Transit Time and Cost Reduction

Figure 8-2 shows an illustration on how to shorten transit time of intermodal transport and how to reduce transports cost. Recognizing that the system has integrated functions, a total system approach from origin to destination could be helpful in finding solutions to problems over the intermodal transport system.

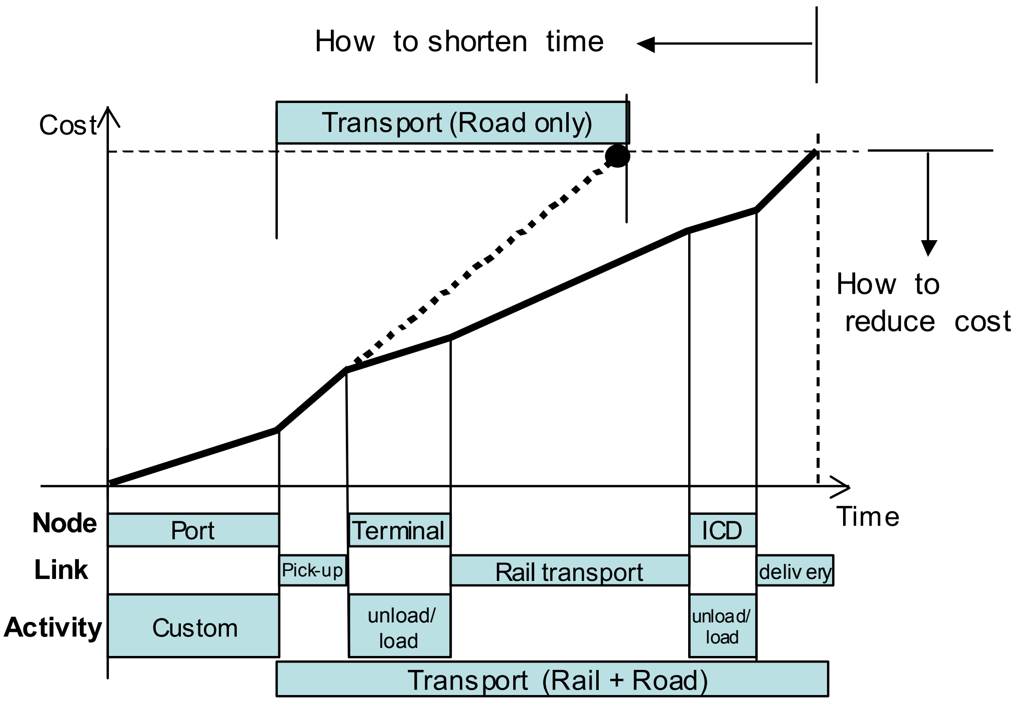


Figure 8-2 Linkage of Time and Cost in Logistics

The solution is found among the node (e.g. harbour, terminal and ICD), the link (e.g. container pickup, the railway transport and truck delivery) and the works in the nodes (e.g. custom clearance, loading and unloading to the train and the truck). Not only physical improvement but also work side improvement should be done by repeating efforts in reducing time and cost. The properties of road and railway have to be compared. The issues on their weakness must be finally considered.

Table 8-1 Properties of Railway & Road

Term	Railway	Road
Transport Cost	○(low)	△(high)
Frequency	△(low)	○(high)
Unload/Load	△(many)	○(once)
Damage	○(low)	△(high)
Custom	△(same)	△(same)

8.1.2 Seamless Logistics Technology

(1) Human Beings

Even if the automation and mechanization have been achieved, the logistics service quality is attributed by the role of humans, manpower in handling freights. In logistics, the role of human labor has drastically changed. Two representative examples are illustrated below.

1) One-stop Service by Multifunctional Drivers

Home delivery service, so-called '*TAKUHAI*' in Japan, has been a part of the Japanese life style. The person who is in charge of the delivery does not only drive truck, but also collects money while delivering parcels. In the absence of the consignee during delivery, he plays the role of a call centre as well. When consignee calls for delivery they go back to the consignee's house again.

Takuhai drivers deliver various parcels like common small dry parcels, golf bags, and others. They also deliver frozen foods that required temperature control and even the everyday meals that require special treatment. From a logistic company's sight, the drivers are multifunctional work force, which could bring cost reduction to the company. Freight companies entrust to the drivers anything for one stop service and this would render the realization of seamless logistics.

2) Logistics Control in Transport

The truck driver running on an expressway has mobile phones. When traffic congestion occurs he promptly communicates with the centre through the mobile phone for new instructions. In some cases, shippers request for new arrangements and reroutes are made. Parallel delivery detours are common for a smooth delivery which became an indispensable service for a modern logistics.

Logistics is recently required to handle exceptional task to strengthen its service quality. A shipper can even move its freights that have already entrusted to a transport company. This means logistics control in transport. Seamless logistics is realized with this case.

(2) Technologies for Seamless Logistics

Here is an introduction of logistics technologies which support the realization of seamless logistics in both sides of standardization and specialization.

1) Standardization and Unit-load system

Modern logistics use unit-loading system, such as palletization and containerization. A cardboard box is designed in such a way it suits palette sizes. Cargo-handling machines are designed also to accord with this palletized freight. A forklift can easily move 1ton unit freight with a palette, resulting dozen times efficient as human labor. Containers are for large freights and large amount of small freights. It is filled with palletized freights and used for out long distance transportation.

Table 8-2 shows the various sizes of palette and container. Each has specific uses depending on a regional area of destination. Because of the demand on each industry or the transport circumstances of each country, the palettes and containers could not be unified. Although there is standard-size of container, all containers could not be classified as global standard because each country has its own allowable freights weight for a 20-ft container.

Table 8-2 Representative Sizes of Palette & Container

Palette	1100x1100 mm (food, others) 900x1100 mm (beer, alcohols) 1400x1100 mm (rice, chemicals)	Japan, Korea Japan Japan
	1165x1165 mm	Australia
	1200x1000 mm	Canada, Mexico
	1200x 800 mm	Europe
	48 x 40 Inch (1219 x 1016 mm)	U.S.A.
The width of container is unified in the world.	40ft	world standard
	12 ft, 20 ft,31ft	JR Freight

2) Multi-modal Transport System (LOLO & RORO)

a) Cooperation in the Vehicles Operation Planning

Trans-shipment is unavoidable in the multi-modal transport that uses various kinds of vehicle as like railways, trucks, ships and airplanes. It is helpful to use common transport tools to reduce time and cost for the trans-shipment.

LOLO is the abbreviation of Load on-Load off, it means that trans-shipment is done using cranes and lifts. Containerized freight has many advantages; not only it shortens work hours but protects the contents from pilferage and environmental damage. It has been playing a big role in the modernization of loading and unloading work in harbor and ports.

RORO is the abbreviation of Roll on-Roll off, it means that transport of freight includes the trucks and the chassis that load freight in. They are just rolling on a ship, a freight wagon or an airplane. In India, *Konkan* railway renders RORO service.

b) Cooperation in Transport Quality

Transport quality has to be improved in seamless logistics. Cold chain is a representative example, which treats refrigeration/frozen goods. Temperature control and management is consistent throughout the transit. Vehicles as like trains which carry refrigerated containers, cold insulation trucks, and facilities such as warehouses and stores are all equipped to control and manage temperature.

The right temperature depends on foods. For fresh fish 0ºC is required, less than 15ºC for the green crop, middle of them for meat products. It is called 3-temperature zone management. There is also frozen foods transportation that requires less than -18ºC to keep foods from deteriorating. In this way, the transportation quality is supported by the cooperation of temperature management for every item.

3) Specialization in Transport Modes

In the case of transporting items in large quantities, specific carrying machines are exclusive used, for transport quality and cost reduction. Specialized vehicles were into common, for instance oil trucks, container ships, exclusive planes carrying huge machines. Specifically, exclusive ships have big cost reduction effects for transporting oil, petroleum products, coal, mineral ores, iron and steel and cars. Because of exclusivity, backhaul are not expected though.

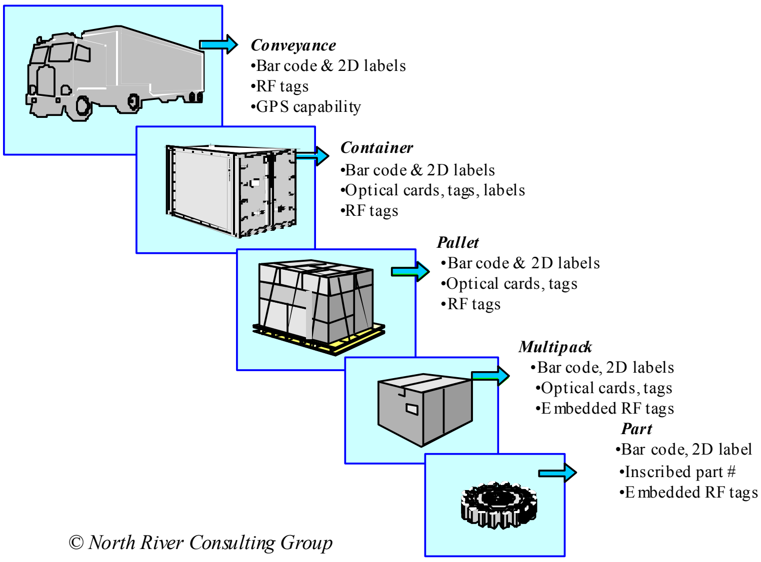
(3) Utilization of IT

In managing intermodal transport, i.e. more than one vehicles and logistic facilities, information is needed to know what process and location the freight is in. Manually was it very difficult to locate its actual location and state of the freight. With the rapid developments in logistics and IT technologies, information can be rapidly acquired accurately. Information on identification of cargo, its location, process status, and information exchange between carriers' for cargo management are available and can easily processed. By applying IT technology, managing the whole seamless logistics process can be made and these are called 'Black-Box'. In other words, "visible logistics" will become a common practice with the help of IT technology.

1) Identification of Freights and Transport Tools

In the logistics, the identification units of materials are different for each company. An identification unit is fixed by a handling unit of a company such that, the maker uses an article cord unit, the wholesale dealer uses a box unit, the long-distance transporter uses a container unit and the distributing company uses a palette or a box unit.

Since each company has their individual information management, it must be known which freight is loaded on which container to realize the seamless logistics. A transport tool performing cross-platform interfacing for seamless information exchange is needed. For example, truck location information can be changed to the location information of the container connected with container numbers loaded on a transport vehicle. Interconnecting information managed at a higher level of the hierarchy with the lower level unit, it is possible to have visible information for seamless transit. Figure 8-3 shows material identification unit and material identification technology hierarchically.



USDOT Intermodal Freight Steering Group, April 29, 1999

Figure 8-3 Identification Units & Identification Technologies of Materials

2) Standardized Label

In addition to the difference of identification unit that is stated above, problem also occurs between companies undertaking seamless transport initiatives specifically on information management. Freight contents details are often written on a sticker label placed on freight boxes. Departure shipper pastes up label on written information such as product number for shipment inspection, order number, customer name and etc. Carrier needs information such as delivery addresses, load figures, capacities, true weights and etc. If labels are different between companies at each transfer points, data input would be painful process in every transit. If information on a label is then interchangeable among shippers and carriers, it is not necessary to replace labels. Moreover, such trouble and risk would disappear over data input process.

For the realization of seamless logistics, it is necessary to decide necessary information and its interchange methods. ISO15394 was established as an international standard label in 2000.

3) Standard Information System

In the company, transit slips are used at each stage in production, order receipt, delivery operation, instructions to carriers and etc. These information contents have many common points. If the company standardizes the information of all stages and the information can be integrated for each purpose, then the data input and posting work in each stage can be significantly reduced. Work time for data input will also be reduced. Information needed for practical use prevents shipment mistakes, stock differences, miscarriages and etc. In addition, they can realize seamless logistics by "standardization of information" and that valuable information are used or supplied on each stage and throughout the logistic transit.

An information system was planned specifically for this purpose. JR freight, a Japanese railway company, developed an IT-FRENS system for container management. This system communizes a series of information that are essential for container transport, departure/destination container stations, container forms, loaded trains information and etc. It can handle reservation management for loading trains, current situation management of container at custody places, container handling freight planning of operation development, calculation of the handling results and etc. In addition, this system is an example of seamless information interchanges among companies. This tool system will be mentioned in the next clause.

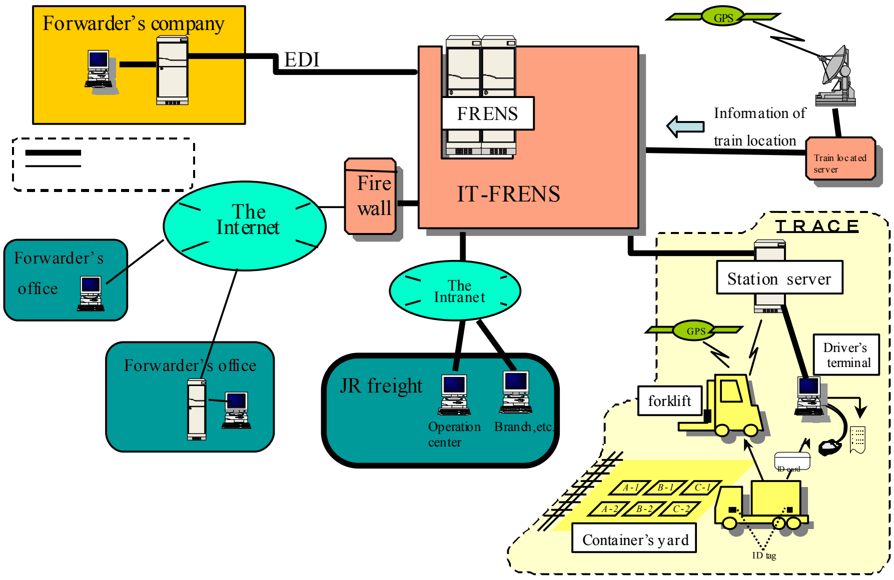


Figure 8-4 A figure of IT-FRENS summary

4) Seamless Information System

In the modern transport, support systems are getting ready for route guidance of ships and trucks and info-service of problems areas, for modes in each link. For example, AIS (Automated Identification System) for maritime and ITS (Intelligent Transport System) for road transport are there. Each transport company will then introduce integrated trucks operation management system, and will undergo performance test run with results on management and truck cargo tracing of the transport modes.

Every one of these links will have a network of support system and trucks operation management system for each company. Then, the network realizes the coherent optimization of cargo tracing and transit route through land and sea. Figure 8-5 is a schematic view of the seamless information exchange in intermodal transport through land and sea.

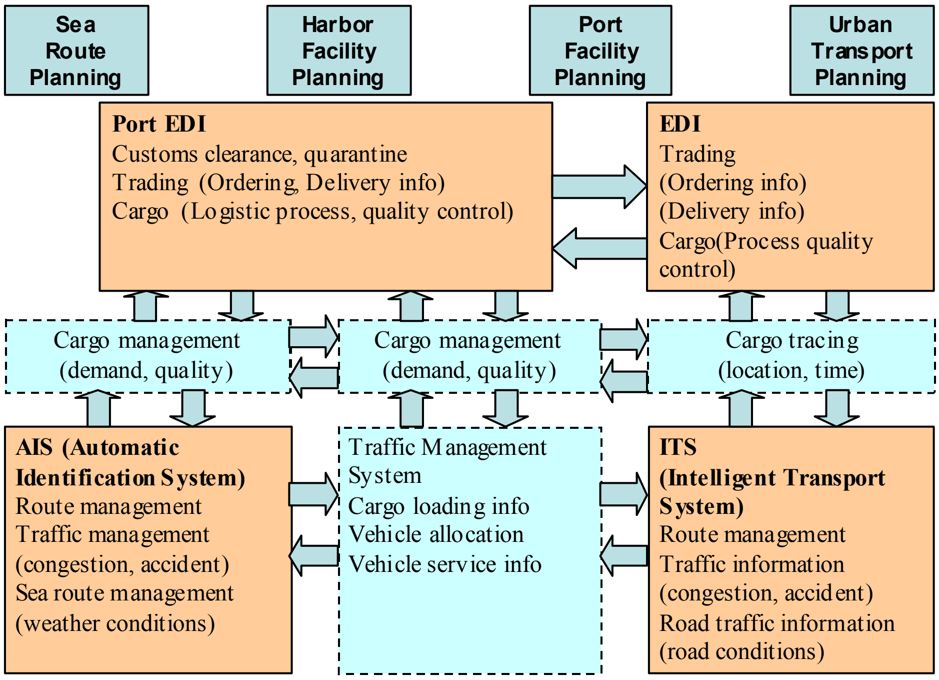


Figure 8-5 Seamless Information in Intermodal Transport through Land and Sea

8.1.3 Seamless Institution System

(1) Consolidation of Legal System

1) Promotion of the Transport Policy

High economic growth changes the structure of transport (freight) and trip (person), and brings the increasing demand of domestic and international transport. In countries of high economic growth, as a preparatory measure, administrations reinforce existing institutions to get ready for the increase in transport demands. However, a sudden economic growth makes arrangement of infrastructure tend to be late; the road expansion program that does not catch up with the increase of car volumes, the limited railway capacity, and the port facilities overloaded with cargo. As a result, traffic congestion occurs in cities and commuting for work or school becomes difficult. Traffic congestion is connected with the increase in traffic accidents and urban pollution. In order to solve these problems, the transport policy must be enhanced for the improvement of road, railway and harbor in swiftness and balance.

2) Support of the Intermodal Transport

Each transport mode has its own related competent authority. That results in some troubles as like complicated application forms and procedures. Promotion of seamless transport system can only be established with regulations and procedures based on the legal system that help to understand the situation of logistics. Training or proper laws need to be based on understanding of Logistic problems. Enforcement of nation statistics in transport as like Freight Flow Investigation or Net Freight Investigation can be efficient tools. Net Freight Investigation removes repetition by the intermodal transport.

(2) Maintenance and Substantiality of the Institution

Transaction methods on many regulatory institutions with many of tariff and charge clearance are custom made for each individual shipper. Standard procedures by institution and clearance system are demanded to meet the seamless logistics transit. Procedures and permits diverge into many branches as follows:

- Administrative institution (customs clearance, quarantine, warehousing industry, port cargo handler and etc)
- Maintenance of the labor circumstances (duty form, vehicle operation method and etc)
- Cooperation of the information system (ministries and government offices interval, official and private cooperation)
- Exhibition of the information (preparation information, results information)
- Railway relations (later payment system of freight tariff and the association of tariff guarantee, mutual account system)

Among above, two railway-related systems will be examined in detail.

1) Later Payment System of Railway Freight Tariff

The railway freight tariff is prepaid as a general rule, but railway forwarders with many freight and containers each day encounter clearance problems troublesome. Clearance is done by bulk from railways authority based on shipment once a month, which is referred to “future payment system” for railway freight tariff. It will be more favorable for a railway forwarder by paying a deposit to the association of tariff guarantee. The deposit charges are fixed amount per tariff amount. When a railway forwarder was not able to pay the tariff by any chance, the deposit money is replaced to the tariff.

2) Mutual account system

This is a charge clearance system, when railway forwarders in departing place and arriving place transit with each other. Railroad forwarder “A” in departing place will pay delivery charge to railroad forwarder “B” in arriving place, and vice versa. In principle, they offset each other's payment charge and clear only for payment of the net difference. Actually most railway forwarder participates in this structure, and they clear accounts it using computers once a month. For direct payments, freight charges are paid from the start of the freight, but this payment structure is few as compared with other structures. If there are mistakes in ordering, the forwarder is adversely requested for payments in the next month.

(3) Maintenance of the Legal System about the Distribution Center Setting (A Japanese example introduction)

An introduction for seamless transport and institutional policies is below with the Japan example.

Locating distribution center and logistics center in a specific area will reduce traffic congestion in a city. In addition, if railway freight stations, ICDs and truck terminals are located adjoining each other, it will promote intermodal transport among rail, road, maritime and air.

In Japan high growth started in 1966 and ten years later a law “Maintenance of Distribution Center in the City” was promulgated. This law details the location of logistics centers, truck terminals and other related facility on specified area exclusively used for promotion of efficiency of the logistics activity in a big city. This law is intended not only for the distribution centers of the companies but also the maintenance of institutions such as wholesale markets, warehouses and distribution processing. This law contributed to Japanese logistics promotion of efficiency.

With "Compulsory Purchase of Land Act", on the other hand, land usage is strictly limited in a distribution complex. That brought an inefficiency of being able not to meet various distribution demands. Therefore this law was revised in order to improve usage capacity in 1993.

In 2005, the law on "Comprehensive of Distribution Centers and the Promotion of the Efficiency" was passed with the aim of establishing efficient distribution system that is compatible with residential environment, global environment problem, and for the effective location methods of distribution center.

This shows a big role of the legal system in promoting efficiency of distribution.

8.2 TRACK TECHNOLOGIES FOR HIGH AXLE LOAD

High axle load railway in North America and Australia use Head Hardened rails, whose head is heat-treated because wear of high axle load rail progresses faster than the normal railway rail.

Wear-proof of Head Hardened (HH) rails is improved and hence the replacement cycle of this rail becomes longer. Thus, maintenance cost is reduced. The carbon content, an ingredient of rail material is increased, compared with normal rail and chromium is included as an alloy ingredient. Vanadium is also included, if needed.

There are 2 standards of surface hardness of rail head: the Brinell hardness 340 (HH 340) and 370 (HH 370).

Recently, development of a Thermo-Mechanical Control Process（TMCP） steel rail is in progress. This type of rail avoids unnecessary heat treatment and is still wear-proof; also its fatigue damage resistance characteristic are improved compared to HH rail. TMCP steel aims at improving the intensity of steel and its improvement in toughness by controlling composition of steel using hot-rolling and a cooling process effectively as a thermo-mechanical treatment process. As for the TMCP steel rail, in North America, the actual verification experiment has already started.

8.2.1 Track Maintenance and Rail Failure in Indian Railway

It is known that presently rail breakage occurs frequently in IR. However, the actual conditions are not clear since formal data on the quantity, its cause and contents have not been obtained. At least it can be said that welding, both shop flash butt welding and on-site thermit welding, is of poor-quality, since so many reinforcement fishplates were found installed. For both IR and DFCCIL it is important to secure the quality and technology of rail welding.

Failure and deterioration of rail form by following factors is shown below. Rail rehabilitation/replacement by failure or degradation accounts for a considerable part in the cost of railway track maintenance. Therefore, reduction of such cost is an important element for sound management of railways assets.

a) Decrease of a section of the rail head by wear caused by rolling friction
b) Decrease of the section inside of the rail head by wear caused by friction with wheel flange in a curved track

c) A crack which develops beginning from micro-cracks at surface of the rail which are caused by rolling contact fatigue by repetitive wheel running

d) A crack which develops beginning from an interior spot of the rail caused by rolling contact fatigue again by repetitive wheel running

e) A crack which develops beginning from an interior spot of the rail which is an impurity formed in production process.

f) A crack which occurs at the welded section caused by poor-quality welding

g) A crack which occurs from a bolt hole of a joint at the rail (rail-end failure) or at the fish plate.

Out of failure/deterioration of rail, the wear, mentioned above in (a) and (b), depends on the age, which can be coped with inspection and timely replacement. But others bring accidents by sudden breakage or require additional replacement before its life expectancy or repair work based on findings by regular inspection of ultrasonic flaw detection which increases the maintenance expenses (the replacement and rail costs by its life shortening).

Against the above-mentioned factors the following countermeasures can be applied, which are being done by respective railways to their utmost capacity not to reduce the life expectancy of rails.

- The wear in a sharp curves, mentioned above in (b), can be reduced by using HH rail (Head Hardened rail: heat-treated rail, quenched rail), as it is broadly adopted in worldwide railways. PETS-II has proposed to use HH rail in the curves of radius equal to/less than 873 m (i.e. 2 degree).
- The wear in a straight section (and a loose curve), above mentioned in (a), is very little. Rail replacement is carried out by longer time cycle, and there are no problems.
- Recently a crack which develops from a micro-crack at the surface caused by rolling contact fatigue, above mentioned in (c), is occurring frequently, due to higher speeds and increased weight/load of trains. In IR as well as other railways bruises on the surface of the rail are seen. It is recognized generally that grinding the rail surface to remove the surface fatigue and micro-cracks and make the surface like new before the micro-crack grows is an effective countermeasure.

  Periodic rail grinding is carried out in many railways recently. It is reported that Tokaido Shinkansen in Japan has succeeded to get rid of such rail failure by executing rail grinding about 0.1 mm once a year. It is indispensable that the periodical rail grinding is put into the track maintenance system of the DFC when it is put to practice.
- It is said that a crack which develops from an interior spot caused by rolling contact fatigue, above mentioned in (d), often occurs in high axle load railways in North America and others. It requires further study to clear its mechanism and countermeasures. In North America heavy haul railways tend to adopt HH rail in straight sections in order to reduce rail failure of interior spot, which is caused by rolling contact fatigue under condition of heavy axle load
- Rail failure of interior spot, which is brought about due to an impurity formed in producing process, mentioned above (e), has become less recently, since quality control of steel-manufacturers has increased. There are no problems if suppliers are selected carefully.
- Concerning the defects in welding caused by poor-quality, mentioned above in (f), the first thing to do is to increase quality control and technology of welding. When the system of both track construction and track maintenance for the DFC is put up, this has to be adopted as one of the most important matter resulting in getting rid of the problem.

- Bolt holes, above mentioned in (g), are weak points of the rail as well as are with the rail joints. Currently, the rail joints have been decreased by wide adoption of continuous welded rail. However, rail joints still remain and they should be maintained carefully.

To know the current state of the rail of IR, observation was carried out at 3 points near Delhi. Defects of both shop welding and on-site welding are pronounced. From the extent of observation carried out, no clear trace of damage or breakage of rail body was found, though fatigue damage on the rail surface was seen.

It is said that the number of occurrences of rail breakage accidents are about twice a year within the jurisdiction of the track maintenance office (about 100 km of route length) where these are noticed. It can be said these are too many. Though the condition, such as axle load is different, in Japan, in the railway length of about 20,000 km (route length of JR Group) only less than 10 nos.of rail breakages occurs in a year with no derailment.

It seems that RDSO has the formal recorded data of defects and failure of rail in the whole IR system, about its quantity, causes and contents. It could not be obtained till now. This data is an important element for drawing the plan on construction and maintenance system of DFC. Acquisition of this data is indispensable for this and successive studies to produce relevant and useful results.

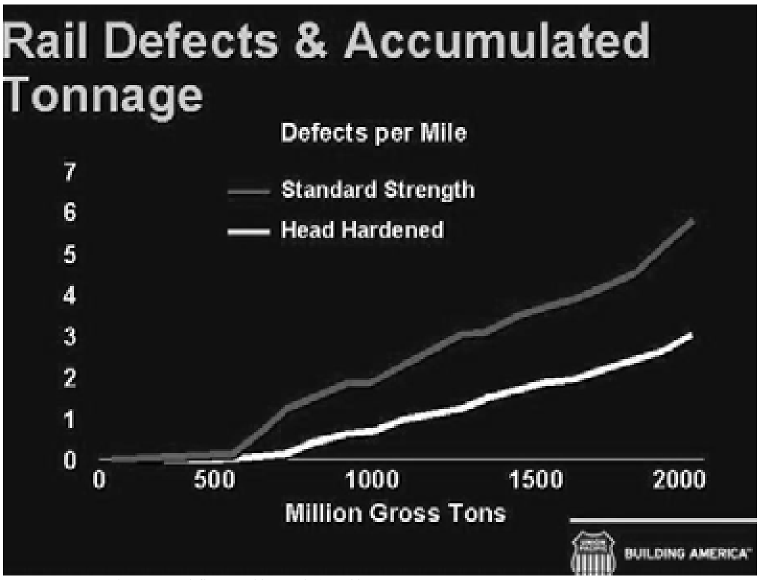
8.2.2 Subject to Be Examined on High Axle Load Railways and HH Rail

In order to raise efficiency of freight transport, railways in North America and for mineral transport in some countries had to increase axle loads. The DFC is planning to adopt high axle load of 25 ton in the first stage and 30 ton in the future. With adoption of higher axle load larger degree of wear and damage of rail is expected. Defects of rail caused by high axle load may showup. Therefore, further examination of measures is required.

Adoption of HH rail in sharp curves, periodic rail grinding and high level welding are the proper measures required for the DFC. The issues described below can be listed as further countermeasures. These include those that have not been clarified at present. As they seem to be effective, they have to be examined further to be applied to DFC track planning.

It is said that a crack which develops from an interior spot caused by rolling contact of high axle load occurs in railways in North America and other railways, HH rail has been adopted in straight/loose curve sections to be used as a countermeasure. However, sufficient data on logical grounds and actual results have not been obtained; further studies are required to be carried out.

Comparison between HH rail and normal rail concerning the relation between the accumulated tonnage and the rail defects found during inspection of ultrasonic flaw detection is shown in Figure 8-6. Based on this it can be said that there is advantage of HH rail in straight/loose-curved sections under high axle load in North America of more than 30 ton. However, to make sure of this effect under the axle load of 25 ton at the beginning of operation of DFC needs further examination.



Source: Union Pacific Railroad (Railway Age, Jan. 2007)

Figure 8-6 Relation between Accumulated Tonnage and Rail Defects

Concerning a crack which develops from a micro-crack at the surface caused by rolling contact fatigue, if growth of micro-cracks at the surface can be restrained, life cycle cost can be saved by reducing a cycle or depth of grinding. To adopt HH rail which has increased strength of the rail head by heat-treatment has the possibility to be effective under these circumstances. More studies needs to be carried out to verify this.

8.2.3 Cast Manganese Crossing

A cast manganese crossing is a crossing made of high manganese steel by mono-block casting. Its characteristics are shown as follows:

- It is preserving and hard to crack, and even if a bruise occurs, its development is slow.
- It has a feature of work hardening with passing of rail wheels, which makes it hard up to hardness of Hs 30 to Hs 50-60.
- It has a feature of high wear resistance and it is suitable for heavy load railways. It is to be used all over the turnouts in main tracks of the DFC.

8.2.4 Prestressed Concrete Sleeper

The merit of the prestressed concrete sleeper is as follows:

- It is so difficult to corrode and rot, making its durability period longer.
- As track irregularity growth is low, maintenance cost can be saved.
- As it is heavy and stable, it can make buckling resistance of the track high and so it is indispensable for continuous welded rail.

Under high axle load destructive forces are higher. Hence, it is necessary that the expected quality in the design is secured. Quality control higher than that at present is necessary. Prestressed concrete sleepers of IR at present seem to have many cracks and chips, and it cannot be confirmed that sufficient quality control is carried out.

8.3 AXLE LOAD AND LOOP LENGTH

8.3.1 Axle load

(1) Bulk Freight Wagon

The results of studies in the BOXN type freight wagons, which are the 4-axle open freight wagons commonly used on Indian Railways, are shown in Table 8-3 within the present loop length of 686 m. The 25 tonne axle load targeted for the first stage enables 5,800 gross tonnes with a payload of 4,350 tonnes. Accordingly, this gives a 2.61 ratio of payload to empty mass for the 20.3 tonne axle load, which increases to 3.02 for the 25 tonne axle load. In other words, increasing the axle load by 23 % there is a corresponding of increases of 28 % in payload.

When the axle load is increased to 30 tonnes, the maximum train weight becomes 6,960 tonnes. However, it is possible to haul 15,000 tonnes by extension of loop length up to 1,500 m, the target for the DFC. Hence, by increasing the axle load by 48 % there is a corresponding increase of 58 % in payload. It is possible to operate double coupled train which can provide 13,920 tonnes.

It is only natural that the effect of the 30 tonne axle load is greater than that of the 25 tonne axle load. However, while it would be advantageous to prepare the infrastructure for the 30 tonne axle weight for compatibility with future improvements, based on the studies of the existing infrastructure, the 25 tonne axle weight is desirable for the first stage as it would enable enhanced inter-operability of the feeder lines.

Table 8-3 Axle load and tonnage of bulk train, Case of loop length - 686 m

Axle load (t)	Wagon type	Length (m)	Nos. within 686 (m)	Tare weight (t)	Pay load (t)	Gross (t)	Total pay load (t)	Pay load/empty mass	Ratio as axle load 20.3 t
20.3	BOXN	10.6	58	22.5	58.7	4,700	3,400	2.61	1.00
22.5	BOXN	10.6	58	23.6	66.4	5,220	3,850	2.81	1.08
25	BOXN	10.6	58	24.9	75.1	5,800	4,350	3.02	1.16
30	BOXN	10.6	58	27.3	92.7	6,960	5,370	3.40	1.30

(2) Container train

The results for container wagons are shown in Table 8-4 in case of the 686 m loop length. These results are based on the four-axle BLC-type container wagon used by CONCOR for container transport and assume that the containers are double-stacked. A maximum of 45 wagons can be transported in the 686 m loop length. The axle load of 25 tonnes targeted in the first stage gives 4,500 tonnes of gross train weight and 3,600 tonnes of payload. At the 25 tonne axle load, the payload to empty mass ratio is 4.00, an improvement from the 3.28 ratio at the 20.3 tonne axle load. In other words, there is 28% increase in payload from a 23% increase in axle load.

And, as with the bulk freight trains, a double coupled train can provide a total gross train weight of 9,000 tonnes hauling the equivalent of 360 TEU.

The maximum capacity of a wagon is two 20 ft containers or two 40 ft containers at the 20.3 tonne axle load, two 20 ft containers plus one 40 ft container or two 40 ft containers at the 25 tonne axle load, and four 20 ft containers at the 30 tonne axle load.

Table 8-4 Axle load and hauling tonnage of container wagons

Axle load (t)	Wagon type	Length (m) in 5 wagons	Nos. within 686 (m)	Tare weight (t) in 5 wagons	Pay load (t) in 5 wagons	Gross (t)	Total pay load (t)	Pay load/empty mass	Ratio as axle load 20.3 t
20.3	A+B	66.0	45	92.0	311	3,654	2,800	3.28	1.00
22.5	A+B	66.0	45	94.9	350	4,050	3,150	3.50	1.07
25	A+B	66.0	45	100.0	400	4,500	3,600	4.00	1.22
30	A+B	66.0	45	109.6	500	5,486	4,500	4.56	1.39

8.3.2 Loop length

(1) Considerations from Braking Performance

To extend the loop length from 686 m to 1,500 m, will require modifications on stations' layout, signaling system and brake system of rolling stock. The present automatic air brake system adopted in IR requires relatively long response time for braking. It causes longer stopping distance and bigger shock forces affecting each wagon in braking. There are two measures to avoid these problems, namely:-

1) Distribution of locomotives

Additional locomotives are coupled at the intermediate or end of the train for distributing traction power and braking command. However, it cannot synchronize timings of each wagon braking. Therefore, meticulous studies on train dynamics will be necessary to introduce long trains such as 1,500 m length before putting in commercial use.

And it requires remote locomotive control system by wire and/or radio. The later system had been developed in US named as LOCOTROL and the system is introduced in several railway operators for heavy train hauling. However, the radio system needs LCX cable and/or other measures for operating in long tunnels or covered areas.

2) Synchronization of wagon braking

To synchronize braking of wagons, electric command air brake system and electromagnetic automatic air brake system are used stead of automatic air brake system. The detailed information is mentioned in Section 8.4.

(2) Train dynamics on heavy/long trains

In the area of wagon design, the UIC standard is adopted for determining the strength of the wagon. It calls for the 200 tonnes of compressive strength. If heavy train hauling is going to be introduced on the DFC, it would be desirable to consider the more stringent AAR standard in order to ensure more strength to withstand the stress that could be caused by such factors as emergency braking, and the introduction of a new brake system that synchronizes the brake timing and force applied for each wagon. With regard to the new braking system adoption, compatibility with the existing rolling stock should be considered to ensure flexible train operation.

(3) Subjects related to transport

It is required that for elongation of loop lengths at stations, increasing substations' capacity, etc. become necessary for longer train length and bigger hauling tonnage. Higher axle load brings modification of track structure and/or more maintenance workings.

The longer train length may be possible with longer train intervals. To minimize the effects for train operation, it will be necessary to increase passing speed at turnouts in stations and to modify signaling systems.

Two or three locomotives will be needed to haul 1,500 m or 15,000 t train because of limited traction performance of locomotives. In a case of train operations only on DFC lines, it is practical to distribute all locomotives at the train head. It will be subject to reduction or absorbtion of shock forces created at starting or braking. Synchronization of braking efforts and timings of every wagon will be necessary.

With regards to, inter-operation through feeder lines, it is envisaged to couple two trains from the feeder lines where the present loop length limits the train length. There are two measures to couple the trains such as to distribute locomotives at intermediate of the train or to locate all locomotives at the train head after shunting movement.. The former is also able to cut response time for braking and to reduce shock forces.

It is desirable to introduce control system for multiple locomotives in both the above mentioned cases.

8.4 DOUBLE-STACK CONTAINER TRANSPORT

8.4.1 Studies on Examples

Double-stack container (DSC) transport was started in the 1990's in the United States to improve the productivity of railways and to respond to the increasing demand for containerized transportation. Since DSC requires a large loading gauge, especially height, the use of DSC transportation started on west coast lines and then was extended to transcontinental routes and east coast area. Diesel traction was used for these routes including the east coast area under overhead catenaries.

Also Chinese Railway started DSC transport between Peking and Shanghai, about 1,500 km from April 2004 in experiment commercial services[1]. The commercial services by DSC had been started from April 2007. It adopts lower containers such as 8 ft or 8 ft 6 inches loading on well type wagons to keep clearances 5.73 m under AC 25 kV catenary as shown in Photo 8-1. The DSC transportation is planned to extend to other lines[2].

Photo 8-1 DSC wagon running under OHE in China, near of Peking

1 *Information source: Japan Embassy in China*
2 *World Bank Report, No. AB 1807*, date of Appraised 22nd September 2005, Approval 13th March 2006

This chapter also presents the latest technologies that may be applicable to the DFC project, such as logistics management, freight transportation, train operation control system and rolling stock technologies. Technology used for train operation includes telecommunication, signaling, and GPS train positioning systems and operation control systems.

However, when introducing new technologies, it is important to maintain a balance among many factors including cost and performance, inter-operability with existing lines and compatibility with existing E&M systems in order to ensure safety, reliability and maintainability.

Matters relating to the selection of systems for train operation control, signaling, telecommunication and traction should be carefully studied after a comprehensive transportation plan has been fixed in order to optimize the costs-benefit effectiveness.

The DSC wagons used in the United States are well type wagons to reduce total height as shown in Photo 8-2. With this type of wagon, the containers are loaded between the bogies. This means that the ratio of length provided for containers in relation to total train length is relatively small. Articulated bogie systems are being adopted to reduce the ratio.

And Indian side is also doing studies on the DSC and gathering information on DSC under OHE[3].

Photo 8-2 Example of DSC Wagon in the U.S.A.

8.4.2 Technical Possibilities and Restrictions

(1) Wagon Structure

The United States and China use well type wagons for DSC transport. However, well type provide for less numbers of containers loading per train length as shown in Figure 8-7

Articulated structure is adopted to increase loading efficiency in the United States. However the articulated structure contributes to a high axle load. When more than three articulated bogies are connected, the axle load exceeds 35 tonnes. The articulated bogies are not adopted because of 25 or 30 tonne axle load are planned in DFC.

Additionally, the loop length of Indian Railways is limited to a maximum of 686 m. Although the introduction of a loop length of 1,500 m to the DFC is being studied as an option, land acquisition and cost are obstacles to it. Therefore, the use of DSC on flat wagons is being studied to enable Indian Railways to meet its transportation demands. DSC on flat wagons can maximize container transportation on the limited train length. However, matters such as

[3] Chinese Railway's Experiences with Double Stack Container Operation under Overhead Conductor System, R. N. LAL, *Technical Papers, International Seminar on Energy Efficient Electrical System in Rail Sector, IREE,* 22-23/01/07

running stability and the higher loading gauge causing limitations in interoperability with other lines of Indian Railways should be carefully examined before putting DSC into commercial service.

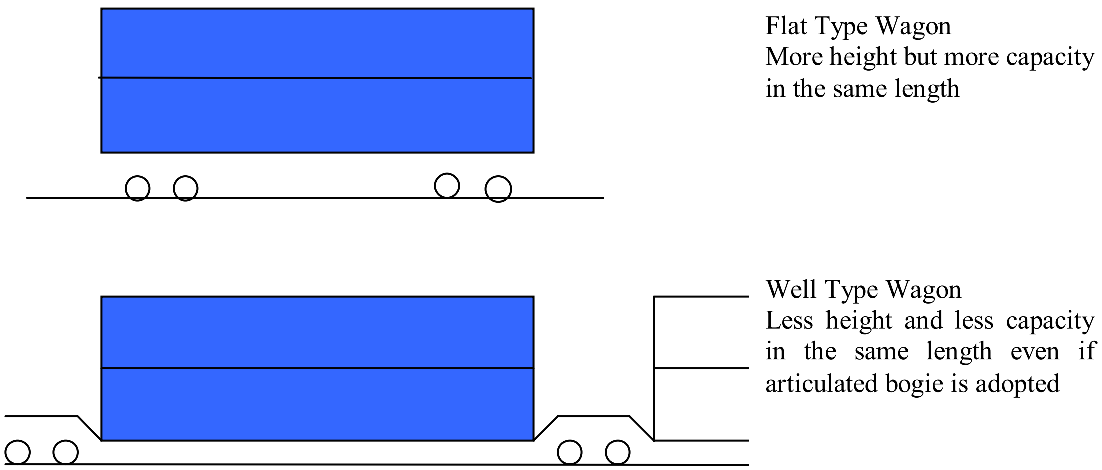


Figure 8-7 Comparison of DSC on Flat and Well Type Wagons

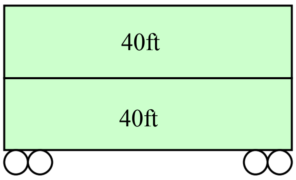
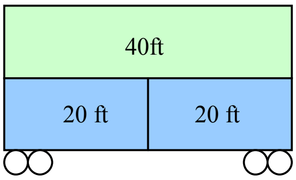
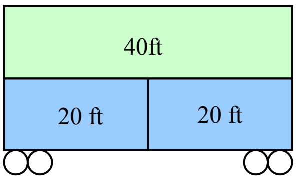
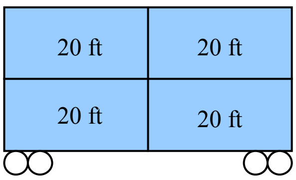
(2) Loading conditions

As mentioned in Section 8.5, the big loading gauge of the DFC enables the introduction of DSC wagons. The use of the flat wagon for DSC is superior to the well-type wagon for increasing capacity within limited loop lengths, such as the 686 m proposed for the DFC.

Tests conducted by Indian Railways show that DSC transport on flat wagons is possible. However, the present axle load of 20.3 tonnes only allows for the loading of two 40 ft containers or two 20 ft containers. An axle load of 25 tonnes would make it possible to combine two 20 ft containers with one 40ft container. A 30 tonne axle load would enable four 20 ft containers to be loaded, although this is very uncommon in actual practice. Each of these cases is shown in Table 8-5. In any case, a light wagon design should be adopted to reduce the tare weight.

There has been some discussion about introducing some form of an articulated structure to the container wagons, such as those used on the railways in the United States. However, if the bigger loading gauge is allowed, the conventional bogie structure would offer superior loading capacity within the limited loop length. Moreover, articulated wagons with more than three units would exceed 35 tonne axle load. Based on the above, the use of such articulated structures cannot be recommended.

Table 8-5 DSC loading conditions corresponding the axle load

Case	Loading condition	Containers	Tare weight	Total weight
1A Axle load 22.5 t		Two 40 ft Load 62 t	A:19.4 t	A:81.4 t
			B:18.4 t	B:80.4 t
1B Axle load 22.5 t		Two 20 ft Load 50 t	A:19.4 t	A:69.4 t
			B:18.4 t	B:68.4 t
2A Axle load 25 t		Two 40 ft Load 62 t	A:20.0 t	A:82.0 t
			B:19.0 t	B:81.0 t
2B Axle load 25 t		Two 20 ft plus one 40 ft Load 81 t	A:20.0 t	~~A:101.0 t~~ Exceeds axle load
			B:19.0 t	B:100.0 t
3A Axle load 30 t		Two 20 ft plus one 40 ft Load 81 t	A:22.0 t	A:103.0 t
			B:20.0 t	B:101.0 t
3B Axle load 30 t		Four 20 ft Load 100 t	A:22.0 t	~~A:122.0 t~~ Exceeds axle load
			B:20.0 t	B:120.0 t

Note 1: In column total weight, "A" indicates leading car is to be coupled with locomotive or another wagon, increases empty weight
Note 2: Empty car weights are estimated in root of the proportion with axle load considering light weight target 95 %.

(3) Running Stability

The higher centre of gravity found on DSC also necessitates a speed reduction when traveling through short curves. The speed limits for both DSC and single-stack containers (SSC) have been calculated using a formula commonly used in Japan as shown in *Volume4 TWP Task 0&1, 8-(1)*. The results are shown in Table 8-6. DSC trains have to be operated 20-30 km/h slower than SSC trains when traveling through curves. Therefore, the effect of the reduced speed of the DSC at these sections should be taken into consideration when selecting DSC or SSC for the DFC.

Table 8-6 Speed Limits at Curves

Unit: km/h

Radius in Meters	Radius in Degrees	Speed Limit for DSC	Speed Limit for SSC
291	6.0	44.2	62.2
437	4.0	54.1	76.2
582	3.0	62.5	87.9
699	2.5	68.5	96.3
873	2.0	76.5	107.7
998	1.75	81.8	115.5

Speed Limit $V=\sqrt{\dfrac{127GR}{2kH}}$

G: Gauge 1.676 m, *R*: Radius in meters, *k*: safety factor, 3.50, *H*: Height of gravity centre in meters

It should be noted the report[4] written by RDSO on the dynamics of DSC, states that there were no problems with stability during its running when measured on the test section between Dhasa and Savarkundla of the Bhavnagar division of the Western Railway. However, since running stability can be affected by a large number of variables, meticulous long-range observations under an array of operating conditions are required. It would be difficult to examine certain variables, such as the differences in the centre of gravity of eccentric loads, during a short-term test that offers limited different track conditions.

PETS-II of RITES mentioned[5] as "*maximum permissible speed of double stack container trains on flat wagons is restricted to 75 km/h.*" giving the impression that there are some problems in stable running of DSC trains. On the contrary, the study team obtained the comment as "*the present speed restriction was not caused by the wagon design but the emergency braking distance required from signaling system. There are no problems on running stability. New designed bogie for 25 tonne axle load can run at 100-110 km/h on DFC lines.*" after these comments from RDSO.

(4) Effect of side winds

Information was obtained that strong winds disturb train operation especially DSC trains in monsoon seasons. It seems there are no regulations to control train operation according to winds in India. Introduction of such regulations should be studied from the viewpoint of improving the overall safety of railways. A further study is done in *Volume3 Task 2 Report Section 5.1.4.*

8.4.3 Subjects relevant to Electrification

Maintaining adequate clearances for DSC trains under OHE is an important issue. DSC trains are being operated under OHE in China and US as mentioned in Section 8.4.1.

RDSO proposes a structure adopting higher OHE corresponding to DSC on flat wagons as shown in Figure 8-8. There are no technical difficulties in this structure. With regards to pantographs of locomotives, these are already available which have wide working range 3.1m to allow from 4.5 to 7.53 m in Europe. Conceptual design is also shown in Figure 8-9.

[4] "Detail Oscillation Trials for Double Stack Container Operation," *Testing Directorate Report* No. MT-64C/F
[5] *Executive summary 4.5.2 Train speeds, PETS II Western Corridor, RITES, 12/06*

Therefore, there are no technical inconveniences in DSC transport under OHE electrified at 25 kV AC. Further studies on OHE and pantographs are shown in *Volume3 Task 2 Report Section 5.2.*

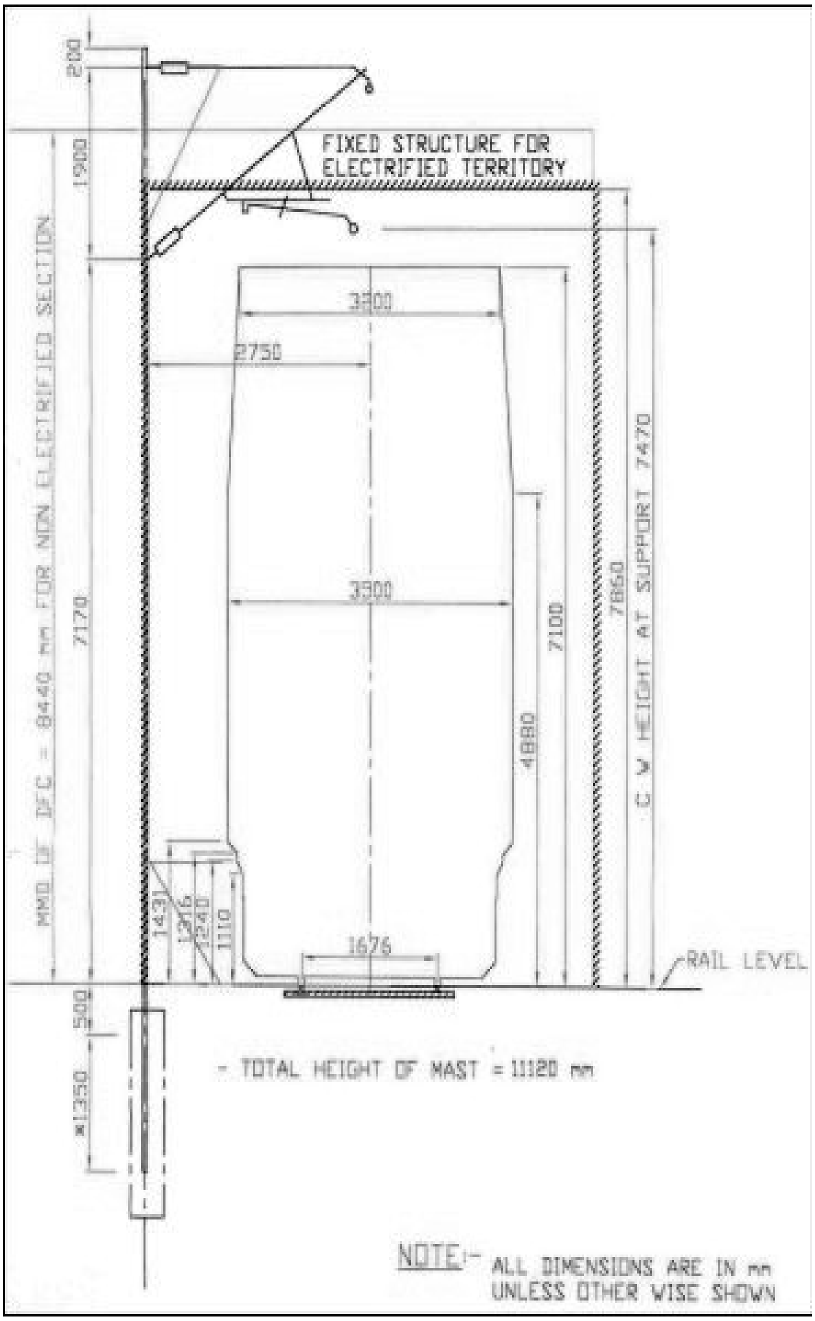


Figure 8-8 Over Head Catenaries adapted to MMD allowing DSC studied by RDSO

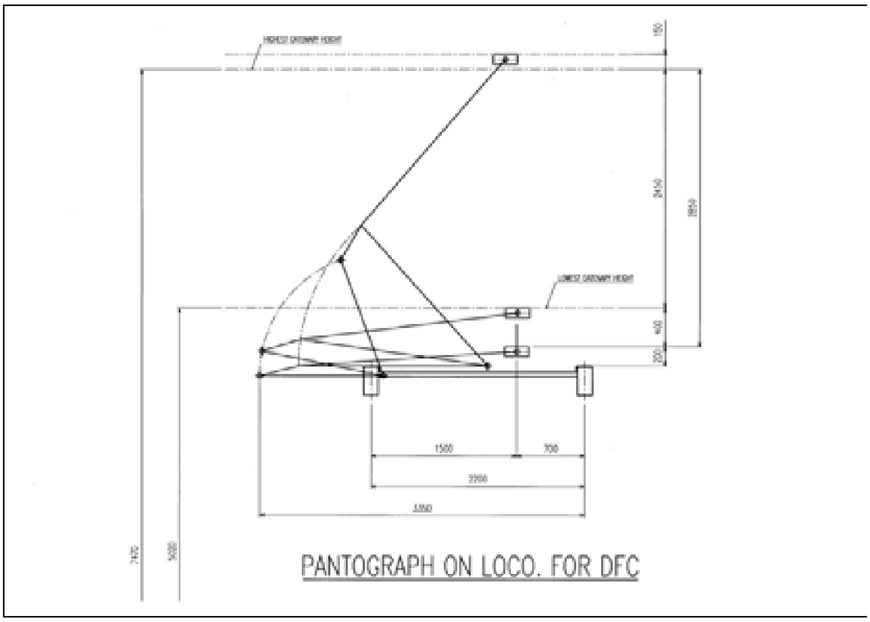


Figure 8-9 Conceptual Design of Pantograph to Allow Higher Working Range

8.4.4 Considerations on through operations between existing lines

(1) Intersection with the existing electrified lines

There have also been some questions raised about the inter-operability of DFC-DSC trains on existing lines and at the crossing or intersections of existing lines. The latter could be solved by meticulously designed track alignment, but further study is needed on new-track alignment in the Delhi and Mumbai areas as these already have well-organized, electrified networks. It should be noted that the subject of inter-operability of DSC trains will remain for the DFC project even if it is not operated under OHE electrification.

Electric locos hauling single stack container train can be operated through the existing electrified lines and DFC lines with higher OHE by adopting newly designed pantograph as shown in Figure 8-9. In this case, the issue reduces to a suitable design of a gradient of OHE transition between lower and higher OHE.

(2) Inter-operability by Diesel traction

In case of the through operation between electrified line and non-electrified line, an exchange of locos at the border is chosen from viewpoints of total trip time and cost. If the exchange affects trip time and cost, diesel loco hauled train will be operated through feeder lines and DFC lines. If not, the loco exchange will be chosen.

In Japanese case, the time required for loco exchange is estimated about 15 minutes.

(3) Operations at container terminal stations

Whatever is the system of traction shunting locos will be needed at the terminal station in general. There, electrified DFC line will require some shunting works at the container terminal stations. In these cases, diesel locos are available to do effective movement for safe loading/unloading of containers on lines without OHE.

The subject whether DSC transport should be introduced or not, must be examined using a thorough total cost-and-benefit analyses, based on total transport planning, including inter-operability with existing lines.

8.5 MAXIMUM MOVING DIMENSIONS AND WAGONS PARAMETERS

The PETS-II Report only addresses the loading gauge in terms of handling loads with large cross-sections, such as double-stacked containers (DSC) and transport wagons as shown in Figure 8-10. 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 DFC may get modified in the final design stage.

The MMD is calculated based on the conditions of wagon's static and dynamic movement. A bigger MMD necessitates larger land acquisition and higher civil engineering costs. Therefore, even if Indian Railways have plans to adopt large wagons in future; removing the door opening condition in the calculation should be considered because by its inclusion, it contributes to higher civil structural costs for the DFC line.

Although the bigger MMD requires larger land acquisition, technical solution is available to allow double stacked container transport at electrified territory as shown in Figure 8-11. Therefore, the subject of introduction of DSC vis a vis Single Stacked Container (SSC) option should be examined by, only economical and environmental aspects, not technical feasibility.

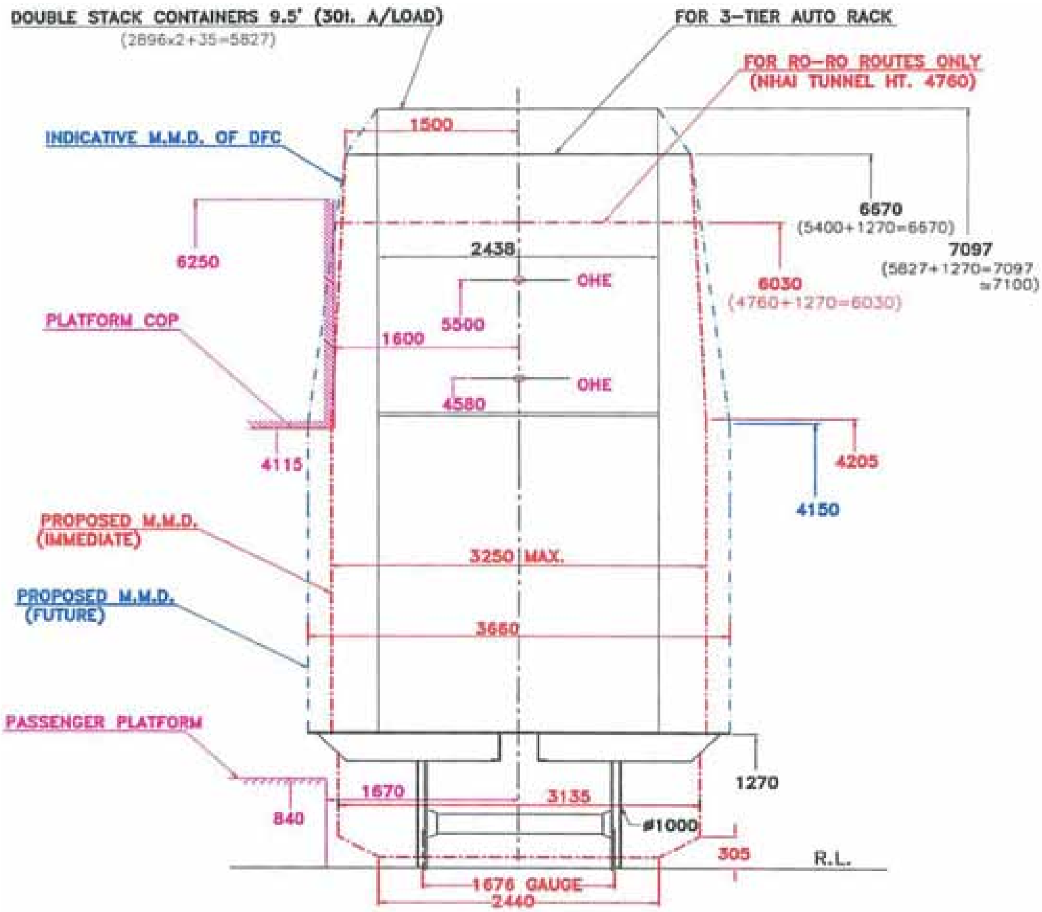


Figure 8-10 MMD Studied by RDSO

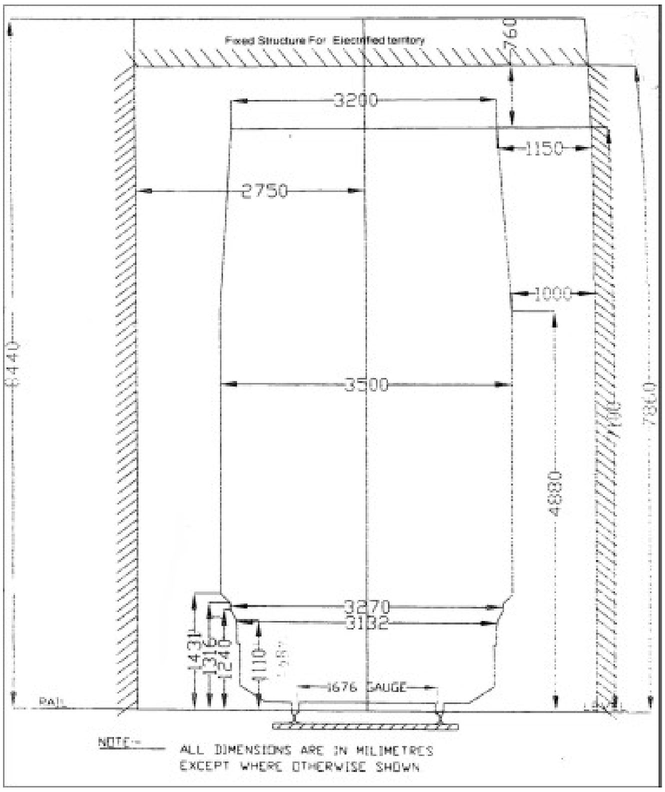


Figure 8-11 Fixed structure gauge for electrified territory of the dedicated freight corridor studied by RDSO

8.6 STRUCTURES

8.6.1 Earth Work

We are aware that a type of reinforced embankment method is being used for domestic road/highway construction in India. It can be seen at the National Highway No.8 construction site now in process near the JICA Study Team Office. On the other hand, there are no actual examples of a reinforced embankment method being used for railway construction in India.

Consideration should be given to using some type of reinforced embankment method for specific locations and/or places with limited heights on the DFC. While approval would need to be granted by MOR, the use of this method in road construction projects may provide ample reason for its suitability in rail construction projects.

Presentation of any actual examples of usage of this method in railway construction in other countries and verification that it is suitable for the applicable high axle load to be used on the DFC may be required for approval. Since the RRR construction method developed at the Railway Technical Research Institute (RTRI) of Japan has been time-proven in railway construction projects including the Shinkansen (Bullet Train), it appears to be sufficiently suitable for 30t high axle loads as well.

The outline and key map of a RRR construction method which are indicated to the homepage of Railway Technical Research Institute is shown below.

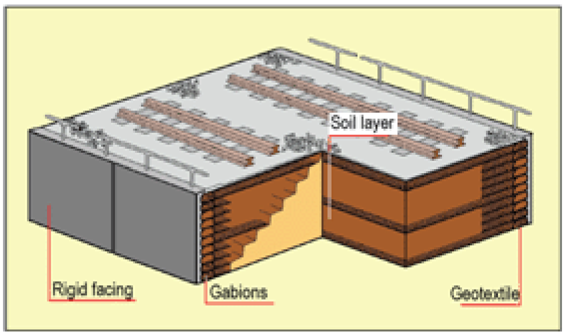
Low-Cost Railways through the Latest Technologies of Design, Construction and Maintenance

One of the most important issues for railway management is to cut the costs involved in construction, manufacture, facility maintenance and rolling stock without loss of reliability. Aiming at a lower-cost railway service, the RTRI is currently working on research in a range of fields, including extending the life of facilities and rolling stock, developing rational design and construction technology, and more efficient inspection, diagnosis and evaluation methods for these railway assets.

Examination of Design and Construction Methods

RRR (Reinforced Railroad/Road with Rigid Facing) construction method

This method is to construct permanent retaining walls having vertical wall face by reinforcing the backfill soil with a geotextile and by using a full-height rigid facing. The area to be occupied for railways can be reduced considerably by this method compared to conventional embankment with gentle slope. The wall constructed by RRR method exhibited high seismic stability during 1995 Hyogo-ken Nambu earthquake.



Concept of RRR construction method

Source: The Homepage of Railway Technical Research Institute (http://www.rtri.or.jp/rtri/lowcost_E.html)

8.6.2 Bridges

The bridge span length of the existing line on this project is approx. 30~70m and the type of bridges are mainly PC-T section girder or Steel plate girder.

Figure 8-12 shows the relation between span length and suitable bridge type. According to this figure, suitable bridge types are selected on the existing line.

Regarding the above situation, the following technique will be proposed for this project.

(1) High Tension Bolting

Rivet connection is applied for site joint of bridge members for long term in India. In Japan, although till 40 years the rivet connection was being used but it is not used now. The reinforced plate for rivet connection to compensate lack of section due to connection holes will become thicker than one of high tension bolt , because more number of rivet hole is required for the smaller strength of rivet.

High tension bolt connection makes the construction period shorter, because the number of the high tension bolts beceme less than those for rivets. As for this project, the construction period is limited and the critical item of the project is the bridge construction, therefore shortening the period by using the high tension bolt connection appears necessary..

(2) Atmospheric corrosion-resistant steel

When the maintenance cost after completion is considered, the cost for steel corrosion will take most of it. The reduction in the maintenance work for the corrosion will reduces the total cost. Accordingly, using “Atmospheric corrosion-resistant steel” is proposed as our technique for steel structures is advanced. The principal of this steel is the close corrosion made on the steel surface prevents the steel from rusting continuously. Although the effect is influenced by the climate condition at construction site; if salt air is not much, no problem will be occurred. In most of the cases, coloring is not applicable, but after the close corrosion on the surface steadies, the surface becomes dark brown color as shown on Figure 8-13.

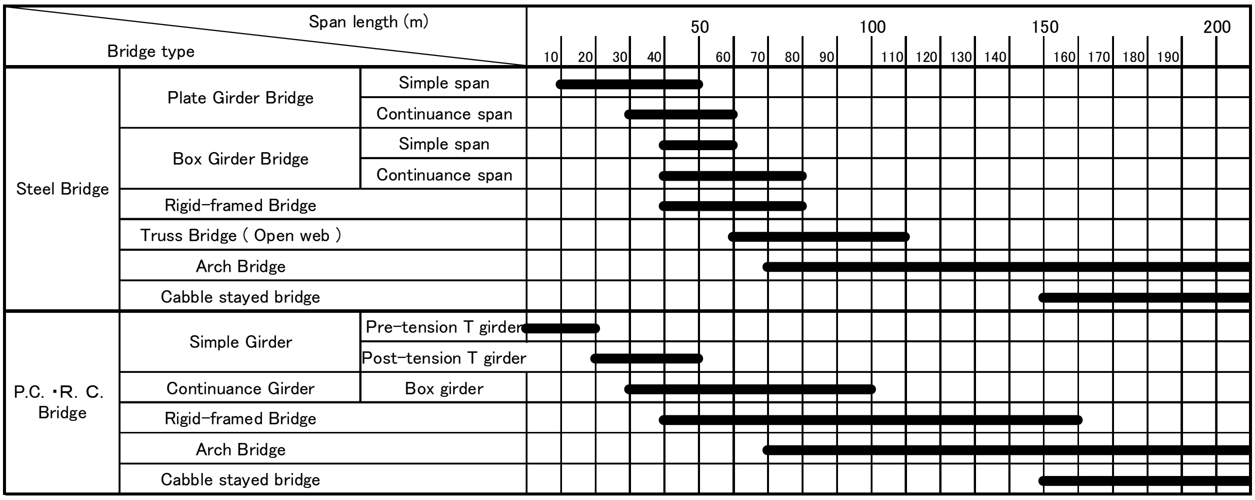


Figure 8-12 Suitable bridge type due to span length

Figure 8-13 Bridge using Atmospheric corrosion-resistant steel

8.7 ROLLING STOCK

8.7.1 Latest locomotives for high speed heavy hauling

(1) Electric locomotives

Three-phase asynchronous motor drive technology was developed in the 1980's through advancements in power devices. Japanese and European companies have superiority in this area at the present. As shown in Table 8-7, the latest locomotives using this technology can provide a maximum power of 1,600 kW (2,180 hp) per axle for European gauge, and 1,000 kW (1,360 hp) per axle for 1,067 mm gauge.

Dynamic braking system technology is also advancing. The latest systems incorporate regenerative braking to save energy and to reduce weight.

In the area of power devices, Insulated Gate Bipolar Transistor (IGBT) technology replaced Gate Turn Off (GTO) thyristor technology from the late 1990's. The high frequency switching of IGBT technology increases cost performance and reduces electro magnetic interference to signalling and telecommunication systems.

The latest technology can be introduced for locomotives on DFC. However, maximum power will be reduced to about 70 % due to the differences in climate conditions found in India in comparison to Japan or Europe.

Table 8-7 Latest Electric Locomotives in Europe and Japan

Builder	Type	Electric	Gauge (mm)	Maximum Power	Axle arrangement	Total mass(t)	Notes
Alstom (France)	ASTRIDE BB36000	25kV50Hz/ 3kVdc/ 1.5kVdc	1,435	6,000kW (8,000Hp)	Bo'Bo'	88.0 t	3phase/ GTO
	PRIMA EL 4200B	25kV50Hz/ 1.5kVdc, etc.	1,435	4,200kW (5,600Hp)	Bo'Bo'	90.0 t	3phase/ IGBT
Bombardier (Canada/Germany)	TRAXX F140 AC	25kV50Hz/ 15kV16.7Hz	1,435	5,600kW (7,500Hp)	Bo'Bo'		3phase/ GTO
	TRAXX P160 AC2	25kV50Hz/ 15kV16.7Hz	1,435	5,600kW (7,500Hp)	Bo'Bo'		3phase/ IGBT
Siemens (Germany)	ES64F4	25kV50Hz/ 15kV16.7Hz/ etc.	1,435	6,400kW (8,500Hp)	Bo'Bo'	87.0 t	3phase/ IGBT
	EG 3100	25kV50Hz/ 15kV16.7Hz	1,435	6,500kW (8,700Hp)	Co'Co'	132.0 t	3phase/ GTO
	DJ 4	25kV50Hz	1,435	9,600kW (12,800Hp)	2 (Bo'Bo')	184.0 t	3phase/ GTO
Hitachi (Japan)	EF200	1.5kVdc	1,067	6,000kW (8,000Hp)	Bo'Bo'Bo'	100.8 t	3phase/ GTO
Kawasaki/MELCO (Japan)	EF210	1.5kVdc	1,067	3,390kW (4,600Hp)	Bo'Bo'Bo'	100.8 t	3phase/ IGBT
Toshiba (Japan)	EH500	20kV50Hz/ 1.5kVdc	1,067	4,000kW (5,300Hp)	2(Bo'Bo')	134.0 t	3phase/ IGBT

Without a fixed transport plan, it would be very difficult to estimate the performance requirements for the locomotives to be used on the DFC. An 8-axle locomotive with power of more than 1,100 kW (1,500 hp) per axle will be needed if, for example, the operating condition called for hauling 5,800 tonnes in a train consisting of 58 wagons with a 25 tonne axle load on 1/200 gradient and running at 100 km/h on level track. If the existing electric locomotives, such as the WAG-9 class, were to be used for this example, two locomotives would be required.

(2) Diesel locomotive

High-power diesel locomotives over 2,000 Hp use electric power transmissions instead of hydraulic transmissions. Companies in the United States, Europe and Japan are all building high power diesel electric locomotives; the highest powered ones come from the United States. Refer to Table 8-8. The latest one has 6,000 hp with 6 axles. Asynchronous AC traction motors are also introduced in the latest diesel locomotives instead of DC traction motors. The propulsion system adopted for diesel locomotives is almost the same as for electric locomotive, with the main difference being that the diesel locomotive use a lower voltage[6]. Dynamic braking technology is also introduced to diesel locomotives, but at the present time only rheostat braking is being used.

Table 8-8 Latest Diesel Electric Locomotives in U.S. Europe and Japan

Builder	Type	Gauge	Maximum Power	Axle Arrangement	Total Mass	Traction
Alstom (France)	PRIMA DE 43C	1,435	2,880kW (3,840Hp)	Co'Co'	123-150 t	AC/AC
GE (US)	AC6000CW	1,435	4,500kW (6,000Hp)	Co'Co'		AC/AC
GM/Siemens (US/Germany)	SD 90 MAC	1,435	4,500kW (6,000Hp)	Co'Co'	190 t	AC/AC
	SD 70 MAC	1,435	3,150kW (4,200Hp)	Co'Co'	188 t	AC/AC
Kawasaki (Japan)	DF200	1,067	2,700kW (3,600Hp)	Bo'Bo'Bo'	90 t	AC/AC

Assuming the same operating condition as mentioned above in the electric locomotive example, two 6-axles diesel locomotives with 6,000 hp would be needed; three would be needed, if WDG-4 locomotives with 5,000 hp were used.

In this calculation, the efficiency of power transmission from the diesel motor to the traction motor is assumed to be 90 %. This means that a 6,000 hp diesel locomotive is equivalent in power to a 5,500 hp electric locomotive.

8.8 ELECTRIC FACILITIES

8.8.1 Review of PETS-II

PETS-II Report describes as follows:

- On the Eastern Corridor, the existing substations will be used to supply electric power for DFC line. The electric facilities are based on Booster Transformer (BT) and Returning Condenser (RC) feeding system same as the existing line. Construction of transmission lines and substations is not considered.
- On the Western Corridor, the idea of diesel traction has been adopted and there is no mention of electrification.

However, the premise of the PETS-II Report was changed by the newly appointed DFCCIL which will design, construct, operate and maintain the DFC lines. Then, the concept on the electrification to be applied for Eastern and Western DFC will be re-examined after the above

[6] Electric locomotives use about 2,000 V as the maximum supplying voltage to the traction motors. However, diesel locomotives use about 700-1,000 V as maximum supplying voltage. The difference is caused by the power source for each. Because of this, the electric locomotive has to use high voltage devices, which cost more, while the diesel locomotive can use low voltage devices.

mentioned condition. Then, totally new facilities should be constructed independent of the existing lines. The new system will contribute to accelerate the project completion, to realize high reliability and high safety, and save energy cost on high speed freight train operation at a relatively low cost.

As per the results, it is desirable to adopt Auto Transformer (AT) system instead of BT system on DFC lines by considering the merits of AT system such as longer distance between substations, lower voltage drop and no necessity of AC sectioning.

8.8.2 Proposal on Electrification

The proposed system is as under:

- Two circuits of 220 kV three phase AC will be taken from the commercial grid of extra high voltage (EHV) to feed directly the traction substations for railway electrification. This system of EHV transmission is common and extends throughout India.
- Alternatively, 110 kV or 132 kV transmission lines are also available according to regional conditions.
- The report does not discuss various types of high voltage switching box. However, GIS (SF6 Gas Insulated Switchgear) is also worth considering for this application in urban areas, strictly restricting the land acquisition.
- It is not recommended to apply high voltages over 400 kV widely used in the Northern part of India. Because, higher voltage over 400 kV brings bigger hazards, larger insulation gaps and a much larger land acquisition. And for the quantum of power needed at each substation, the length of transmission lines needed at this voltage, it is not expected to be economical
- It is recommended to use Vacuum Circuit Breaker (VCB) in principle to increase reliability and to reduce maintenance costs.
- Optical fibre network should be adopted for communication and signalling system to avoid electromagnetic and static interferences from power lines.

8.8.3 SCADA

It is recommended to introduce Supervisory Control And Data Acquisition (SCADA) system to manage and to operate total electric power supply equipment on the Corridor at the Centre. There are many different SCADA systems in Zonal Railways introduced during various years. These do not have any compatibility with each other. RITES Report has mentioned this fact. It is most important to guarantee the total management system to operate trains effectively on the DFC lines. The SCADA system should have room to unify signalling system in future.

8.8.4 Power Supply for Telecommunication and Signalling System

IR obtains electric power for telecommunication and signalling system from state’s local electricity authority’s grid system. It causes problems for stable electric power supply and it affects train operation’s reliability. On the other hand, power supply for traction is given priority. Therefore, it is recommended to supply power for telecommunication and signalling from traction sub-stations also.

8.8.5 Plans on Electric Power Plants

CEA (Central Electric Authority) is making plans to develop power plants, total 70,275 MW including thermal and hydro plants in India.

The total power of plans relevant the Western Corridor is counted as 15,245 MW by thermal, 980 MW by hydro as shown in Figure 8-14 and Figure 8-15. There are enough capacities to compare with proposed electrification of Western Corridor which requires 126 MW at the year 2013 as assuming inauguration of DFC and 425 MW at the year 2031. And during meetings with MOR and RITES officers it has been mentioned many times that "IR has a priority for supply of electric power". There seems to be no problems in the electrification of the Western Corridor with regards to availability of electric power.

Grids relevant to both corridors are shown in Figure 8-16, hence both corridors are able to access the grid for power supply.

For reference, *Volume4 Technical Working Paper Task0&1, 8-(1)* provides information on developments of power plants in India.

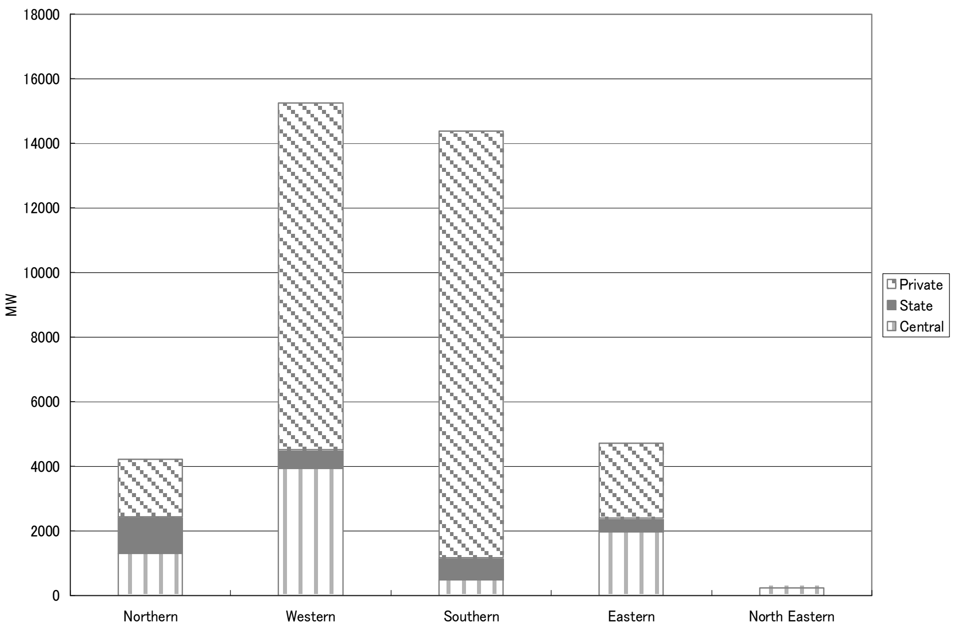


Figure 8-14 Thermal Power Plant Plan cleared/appraised by CEA

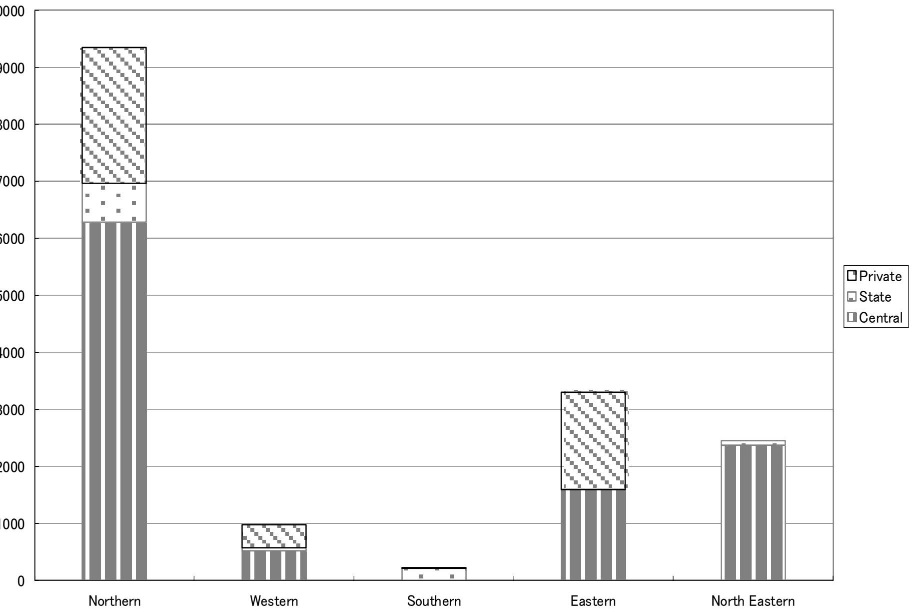


Figure 8-15 Hydro Power Plant Plan cleared/appraised by CEA

Source：Power Map of India 2003, Central Board of Irrigation & Power

Figure 8-16 Grid relevant the Western DFC

8.9 TELECOMMUNICATION AND SIGNALING SYSTEMS

8.9.1 Telecommunications System

(1) Review of the RITES Feasibility Study Report

The JICA Study Team has studied the system requirements and prepared a proposal for a telecommunications system for the Dedicated Freight Corridor (DFC). In contrast, a different study was carried out by RITES Limited and a telecommunications system for the DFC was also proposed in two of their reports: "Preliminary Engineering –cum– Traffic Study for Dedicated Freight Corridor November 2006" and "Preliminary Engineering –cum– Traffic Study for Dedicated Freight Corridor (PETS 2) January 2007".

Table 8-9 below shows a comparison of telecommunications systems that were proposed for the Dedicated Freight Corridor (DFC), as described in the above reports that were prepared by RITES Limited and the JICA Study Team.

Table 8-9 Comparison of Telecommunications Systems Described in the RITES Report (PETS-II) and JICA Study Team

Item	RITES		JICA Study team
	Report (November 2006)	PETS2 (January 2007)	Final Report
1. Fixed communication system			
1) Type	Optical fiber cable	Optical fiber cable	Optical fiber cable
2) System	SDH (STM1, 4)	SDH (STM1, 4)	SDH (STM1, 4)
3) System configuration	Single system	Single system	Double system (Unit redundancy: hot standby)
4) Network configuration	Loop	Not specified	Loop
2. Mobile communication system			
1) System	GSM-R	GSM-R	GSM-R
2) General Function	Voice, Data	Voice, Data	Voice
3) Interval of base transceiver station	10km	Not specified	7km
3. Exchange			
1) Type	Electronic digital exchange	Electronic digital exchange	Electronic digital exchange
2) Capacity	5,000lines: Terminal st. 1,000lines: Junction st. 256lines: Crossing st.	5,000lines: Terminal st. 1,000lines: Junction st. 256lines: Crossing st.	Large: 2,000lines Medium: 256lines
4. Dispatching telephone			
1) Type	Selective calling system	Selective calling system	Selective calling system

Note: St.: Station

Both of the proposed systems are basically the same, as listed above, except for the inclusion of a data communication function in the GSM-R and the interval of base transceiver stations.

The reason why RITES proposed a GSM-R which includes a data transmission function is because they proposed a communication-based signaling system. In order to meet the requirements of communication-based signaling, a mobile data communication function is required between the train and the control station. On the other hand, a conventional signaling system has been proposed by the JICA Study Team. Therefore, if the JICA Study Team proposal is adopted, a GSM-R data transmission function will not be required for the DFC at this point of time. GSM-R is equipped with an expandable function which allows the addition of a data-communications function. The JICA Study Team therefore recommended that the data communications function be added later, when it is needed in the future.

As for the base transceiver station spacing, there is small difference of opinion between the two reports regarding the distance between base transceiver stations.

The propagation of radio waves depends on the “specification of the radio equipment”, “topographic conditions” and “external radio noise conditions”. These factors can be confirmed by doing radio wave propagation tests. It is not planned to carry out radio wave propagation tests in the Feasibility Study (F/S) stage. Therefore, it is recommended that radio wave propagation testing be done in the detailed design stage. After the tests have been done, the required base transceiver station spacing, including radio characteristics, will be known accurately.

The JICA Study Team has noted that there have been reports of GSMR mobile communication problems occurring in some communication sectors which have been designed with a 10 km base transceiver station spacing.

(2) Proposed System

A Special Purpose Vehicle (SPV) will be established for the purpose of making design, budget arrangement, construction, operation and maintenance arrangements for the Dedicated Freight Corridor (DFC) project. Most of the rail tracks for the DFC are planned to be developed along existing rail tracks. In addition, some of existing sections include a communications system. However, in order to separate control and management responsibility from existing facilities operated by Indian Railway's and those that will be operated by the DFC, the JICA Study Team has proposed that a totally new communication facilities be developed for DFC.

Based on the above concept, the following section describes the proposed telecommunications system that will be required for the DFC.

(3) Fixed Communications System

In Indian Railways, optical fiber communications (OFC) systems using Synchronous Digital Hierarchy (SDH) technology have been selected as the next generation fixed telecommunications system because of the capacity, quality and EMC (electromagnetic compatibility) advantages offered by OFC. For this purpose, a total of 42,000 route km of Optical Fiber Cable (OFC) network using Synchronous Transfer Mode (STM) is planned to be commissioned by March 31, 2008. Out of this 42,000 route km, approximately 27,100 route kilometers of OFC had been installed and 23,000 route kilometers had been commissioned as of June 30, 2005. A total of 2,092 stations were linked to OFC, as of March, 2005. In addition, a digital microwave system (generally 7GHz) is operated as a back-up communications system.

The JICA Study Team also recognizes the technical advantages (capacity advantage, electromagnetic compatibility, etc.) of Optical fiber cable communication (OFC) systems when compared to other fixed telecommunication systems, such as metallic cable and microwave communication systems.

Based on current trends in Indian Railways, and the technical advantages mentioned above, the JICA Study Team has selected an optical fiber cable communication (OFC) system that uses Synchronous Digital Hierarchy (SDH) technology as the fixed communications system.

In addition, an optical fiber cable communication (OFC) system using Synchronous Digital Hierarchy (SDH) was proposed in feasibility report which was prepared by RITES Limited.

(4) Mobile Communications System

There are several mobile communications systems available for railway operations, such as Terrestrial Trunked Radio (TETRA), Global System for Mobile Communication for Railway Applications (GSM-R) and other conventional radio systems.

TETRA has been standardized by the European Telecommunication Standards Institute (ETSI) and it is commonly used by public institutions including police, ambulance, fire service, etc.

In contrast to TETRA, GSM-R has been developed with the aim of dedicated use for train operations. GSM-R is an essential component of the European Rail Traffic Management

System (ERTMS) and European Train Control System (ETCS), and it has been standardized under the European Integrated Railway Radio Enhanced Network (EIRENE) project.

TETRA and GSM-R both have duplex communication, data and voice communications systems. However, GSM-R is more applicable to train applications and also allows for expandability for train operation as follows:

1) GSM services
   - Voice broadcast service
   - Voice group call service
   - Enhanced multi-level precedence and pre-emption
   - General Packet Radio Service (GPRS)
2) Railway specific applications
   - Exchange of train number and location information between trains
   - Ground support functions and location dependent addressing
   - Emergency calls
   - Shunting mode
   - Multiple driver communications
   - Direct mode facility for set-to-set operation
3) Railway specific features, network parameters and standards
   - Link assurance signal
   - Calling and connected line presentation of functional identities
   - Cab radio, man-machine and other interfaces
   - Environmental specifications
   - Controller position functional specifications
   - System configuration (numbering plans, priority levels, subscriber details, closed user groups, etc.)

To meet communication needs between train crews and station operators (Station Masters, Controllers, Field Maintenance Staff, etc.), a Global System for Mobile Communication for Railway Applications (GSM-R) system is being introduced on the 'A', 'B' and 'C' routes of Indian Railways.

Indian Railways has secured 9 sets of frequencies for GSM-R and development of GSM-R for over 3,200 route km has been approved by Indian Railways on their Northern, North Central, Eastern, East Central and Northeast Frontier railway lines. These GSM-R facilities are planned to be commissioned by 2008 and some of these system are already being operated.

In addition, development of GSM-R for 2,415 route km is mentioned in the "Integrated Railway Modernization Plan (2005-2010)" and the development contract for this project has already been awarded.

In line with the technical and practical points discussed above, The JICA Study Team proposes that a Global System for Mobile Communication for Railway Applications (GSM-R) be used for DFC mobile communications.

(5) Other Major Communication Facilities

Exchanges have important roles for controlling calls between subscribers. For railways in particular, the exchange provides administrative functions without signaling (securing the system safety) purpose. Compared to an analog switchboard, a digital exchange has the following advantages:

- Low maintenance cost
- Low power consumption
- Less space is required

Indian Railways is now replacing its old analog exchanges with digital electronic exchanges to improve the quality of switching and reduce the maintenance burden. The total number of digital subscribers had reached 274,034 as of March 2005, and 38,469 of these subscribers were connected to digital exchanges during the year 2004-05. All the zonal and divisional exchanges of Indian Railways are being integrated for seamless connectivity by providing a 2 Mbps interface.

Based on the above, the JICA Study Team has selected solid state type digital electronic exchanges with ISDN functions for the DFC telephone exchange system.

The dispatching telephone system also has important roles for ensuring safe and efficient train operation by controllers. There are two types of dispatching telephone systems (i) individual dispatching telephone systems, and (ii) concentrated dispatching telephone systems. In order to reduce the space required for equipment and increase the communication capability between controllers, railway operators tend to develop their dispatching telephone system as a concentrated dispatching telephone system. Indian Railways also tends to install concentrated dispatching telephone system with selective calling functions.

A centralized traffic control centre (CTCC) will be developed in the DFC Project. The DFC CTCC will be staffed by a number of controllers, such as a Traffic Controller, Electric Power Controller, Signal Controller, Telecommunications Controller and Facility Controller.

In order to meet the needs of the DFC CTCC and trend of technology, the JICA Study Team proposes that a concentrated dispatching telephone system with selective calling functions be used for the dispatching telephone system.

8.9.2 Signaling System

(1) Review of RITES Report

The comparison of Signaling in PETS II and proposition by JICA study team is shown in Table 8-10.

Table 8-10 Signaling system comparison between PETS-II and JST

Item	PETS-II by RITES	Proposition by JST
Block Length	Single line section： 10km Double line section： 2km	10km 1～1.5km
Block system	- ABS (Single line) IBS will be added in case of increase of line capacity - Automatic Block System - Communication based Signaling System	Automatic Block System
Train Detection System （Block Section）	- Track circuit (in case of Automatic Block System) - GPS (Communication based Signaling System)	Track circuit
Train Control System	TPWS （in case of Automatic Block System）	ATS-P
Signaling System in Station area	Electronic Interlocking System	Electronic Interlocking System

Review

- Block Length

Calculation condition is shown as follow

	RITES	JICA study team
Line capacity	109 trains per day in 2021	140 trains per day
Train speed	70km/h	90km/h

The result of re-calculation is about 1.5 km length between stations and 1 km near stations when the condition is 140 trains per day and train speed 70 km/h. (Refer to *Volume 3 Task2, Chapter 6 Transport Planning*)

- Block System

PETS II has proposed two systems, one is ABS for single line and automatic block system for double line and communication based signaling system applied with GPS.

Basically automatic block system shall be provided and communication based system will be provided in testing area for technical verification.

JICA study team feels that GPS is premature and we recommend automatic block system. Therefore the proposal by RITES is same stance as our proposal.

- Train detection system

It is not clearly mentioned, PETS II seems to propose track circuit (According to Estimation in appendix of PETS-II). The type of track circuit is not clear.

- Train control system

PETS II recognizes that TPWS corresponding to ATS-P in Japan is required. PETS II is same stance as our proposal.

- Signaling system in station area

PETS II is proposing SSI at station area. Therefore PETS II is taking the same stance as our proposal.

(2) Recommended System

1) Signal System

There is no large difference between the recommended system by PETS II and JICA Study Team. JICA Study Team concludes that communication based signaling system with GPS is premature and recommends automatic block system for DFC.

2) Train detection system

JST recommend the Joint-less AF track circuit as the train detection system. Since this track circuit has a limitation of coverage area, the utilization of a chain of multiple Joint less AF track circuit is proposed to configure the required block length of 1 to 1.5 km.

8.9.3 Power Supply for Telecommunication and Signalling System

According to the discussions with officers from zonal railways, existing power supply for signaling and telecommunication system in IR use directly commercial power from electric power company. The power supply for signaling system and telecommunication system need security and reliability. Therefore redundant supply is required.

Therefore we recommend that high voltage lines from two sources for signaling should be installed at railway side as shown in Figure 8-17.

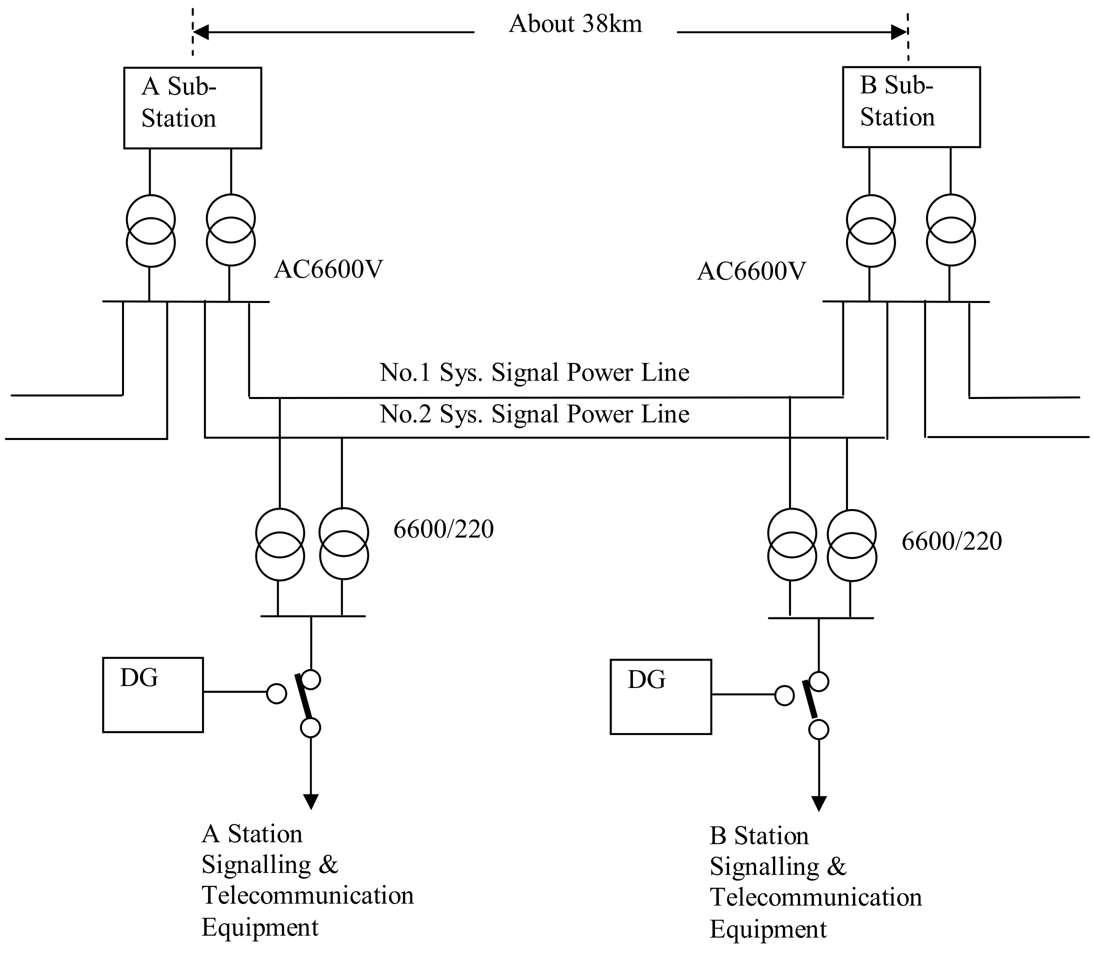


Figure 8-17 Power supply for telecommunication and signalling system

In Japan, 2 system signaling high voltage lines of AC 6600v are installed from 2 different substations and in case of one substation failure, power supply is kept running by changing to other normal substation.

It is recommend this recovering system with redundancy.

8.10 TRAIN OPERATING CONTROL SYSTEM

8.10.1 Need for operation control system on DFC

The following are several reasons why an operation control system is needed on the DFC.

(1) Modern logistics requires punctuality.

From the perspective of current freight transport needs, the DFC requires punctuality more than its speed. The DFC needs to be capable of recovering from train schedule disruptions caused by natural disasters or rolling stock troubles as quickly as possible and restore normal train operations. Moreover, it is also important that information about the operating status of trains be widely conveyed so that train crews and others can correctly respond to changes in operation made by the dispatchers' center. Providing an operation control system for DFC will enable these requirements to be satisfied.

(2) The need for realizing a highly efficient business structure on the DFC.

The DFC requires that its sections should be operated with high cost performance. Reducing the number of personnel to the lowest possible level is desirable. Providing the operating control system for the DFC will make it possible to reduce the number of station personnel.

8.10.2 Traffic operation control functions

Traffic operation control is the system which displays the current position of the train in the dispatchers' centre, giving its staff the information needed for controlling the signals at each station.

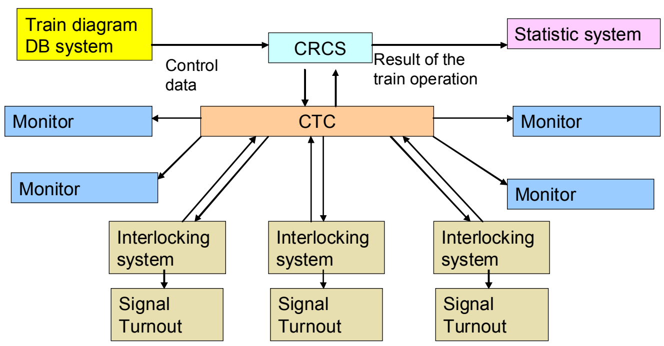


Figure 8-18 Configuration of the Computerized Traffic Operation Control System

The system comprises of the following equipment: equipment that conveys the data between the dispatchers' centre and each station, a train operation display board that is provided in each dispatchers' centre, signal control consoles, and information monitors to show the train operation status information that has been acquired by this system at stations and crew depots. (Refer to Figure 8-18)

8.10.3 The effect of introducing traffic operation control

The DFC is a newly constructed section. The following effects can be expected if an operation control system is introduced to the DFC.

(1) Less personnel required for controlling station signals and routes

The signals at the stations are controlled by the centralized dispatchers' centre so less number of station personnel are needed.

(2) Improved traffic control quality

Since the current train position information is gathered to the dispatchers' centre, it can control traffic based on a full understanding of train operating conditions throughout the entire system.

The dispatchers and the train crews can continue to communicate directly so that the operation of the trains could be effectively controlled. Since there are no intermediary personnel, the dispatchers can quickly and accurately convey instructions to the drivers.

(3) Train operation information provided

Train operation information can be provided to the stations and crew depots.

8.10.4 Latest technical trends in train operation control systems

The advancements in computer technology in recent years have led to numerous developments in the area of train operation control systems. Now there are numerous options for responding to specific needs such as high-density traffic on certain sections of track or varying train operation configurations. The following are a few examples.

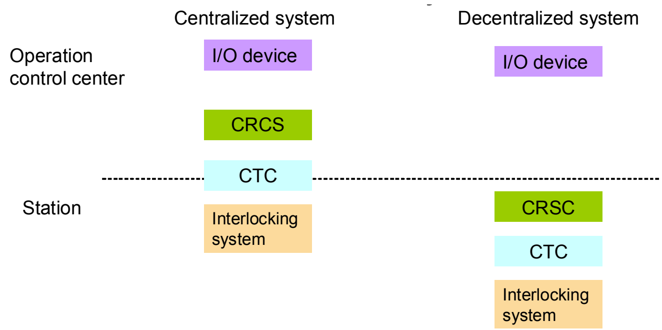
(1) Computerized route control

Route control in the dispatchers' centre can be done manually for low-traffic sections.

And the computer can also be used for route control for sections with high traffic density. The main role of the dispatchers in the centre is to respond to questions from the computer in contingency.

(2) Centralized and decentralized control

A single centralized train operation system is efficient. However, if there is a complicated network of lines or if there are line extensions or other such conditions, a system where control can be decentralized to each station offers merits in terms of expandability. It should also be noted that when a centralized system would happen to fail, this problem affects the entire line. Whereas, with a decentralized system such problems can be limited to a particular section of the line. (See Figure 8-19)



Expandability	Not easy	Easier
Robustness	Not tough	Tougher
Cost	Cheaper	Higher

Figure 8-19 Comparative Features between Centralized and Decentralized System

(3) Compact displays in dispatchers' center

The operating status display board is what is used to display the current train positions in the dispatchers' centre. The information displayed on this board is indispensable for train operation control and this board allows this information to be shared throughout the dispatchers' centre. However, advancements in personnel computers in recent years have made it possible for the information on this board to be displayed on the PC of each staff at the dispatchers' centre, eliminating the need for a single, large information display board. This offers several merits: it reduces facility costs, reduces the amount of space required for the dispatchers' center and it makes it easier to change the layout of the dispatchers' centre. (Refer to Photos 9-3 & 9-4)

Photo 9-3 Dispatchers room with board display (Tsukuba Express)

Photo 9-4 Dispatchers' room without board display

8.10.5 Performance and specification requirements for the DFC operation control system

(1) Performance of the operation control system

Computerized operation control systems are very common these days. Train operation schedule data is required for computer-controlled route plan. It is also possible to accumulate actual train operation data in the system. This data can be used to build various systems. However, since the freight train operation is not limited to DFC, there is a need to input supplemental information from other sections. Because of this, we recommend the following as the minimum functions for starting operation on the DFC.

- Computerized route control.
- Provision of dispatchers with predicted train operating schedules.
- Provision of stations, train crew depots and others with train current operation position information.
- Provide a system that enables maintenance staff to use mobile terminals to close the tracks for maintenance work by themselves.
- Provide a train radio system that enables the dispatchers to communicate directly with train crews.

(2) Design of train operation control system

It is predicted that there will be a limited amount of traffic passing through both the east and the west corridors of DFC. And the length of both corridors is long. Therefore, it would be best if each corridor had its own system. However, if the dispatchers' center was in one location it would facilitate tight collaboration in the control of traffic on both sections.

Indian Railways has a complex network of lines. A decentralized system is desired to fully utilize this network. However, in consideration of its construction cost and the traffic area that should be limited mainly to the DFC at the moment, the centralized system is the most practical. It is desirable that dispatchers for traffic and each engineering section will be gathered together in a room of the dispatchers' centre. If DFC is electrified, SCADA would be provided and it should be controlled in the same room as the dispatchers' centre.

- Design of the centralized system
- Installation of systems for both east and west corridors in the same room of the dispatchers' centre.
- Position SCADA system also in the same room of the dispatchers' centre.

8.10.6 -Hardware of Traffic Operation Control System

Following concepts are recommended for hardware of Traffic Operation Control System.

1) Freight train operates in according to the scheduled diagram.
2) Route setting is automatically executed based on the diagram.
3) It is possible easily to operate the modification and addition of diagram.
4) It is possible to overview and train number, train location, condition of route setting (point position, signal aspect) and traction power condition on the all line and to supervise the traffic.
5) Operation journal date is automatically outputted.
6) This system has redundancy in order to secure high reliability.
7) It is flexible to add new system (Freight management system）.

Hardware configuration is as shown in Figure 8-20 in order to realize above concepts.

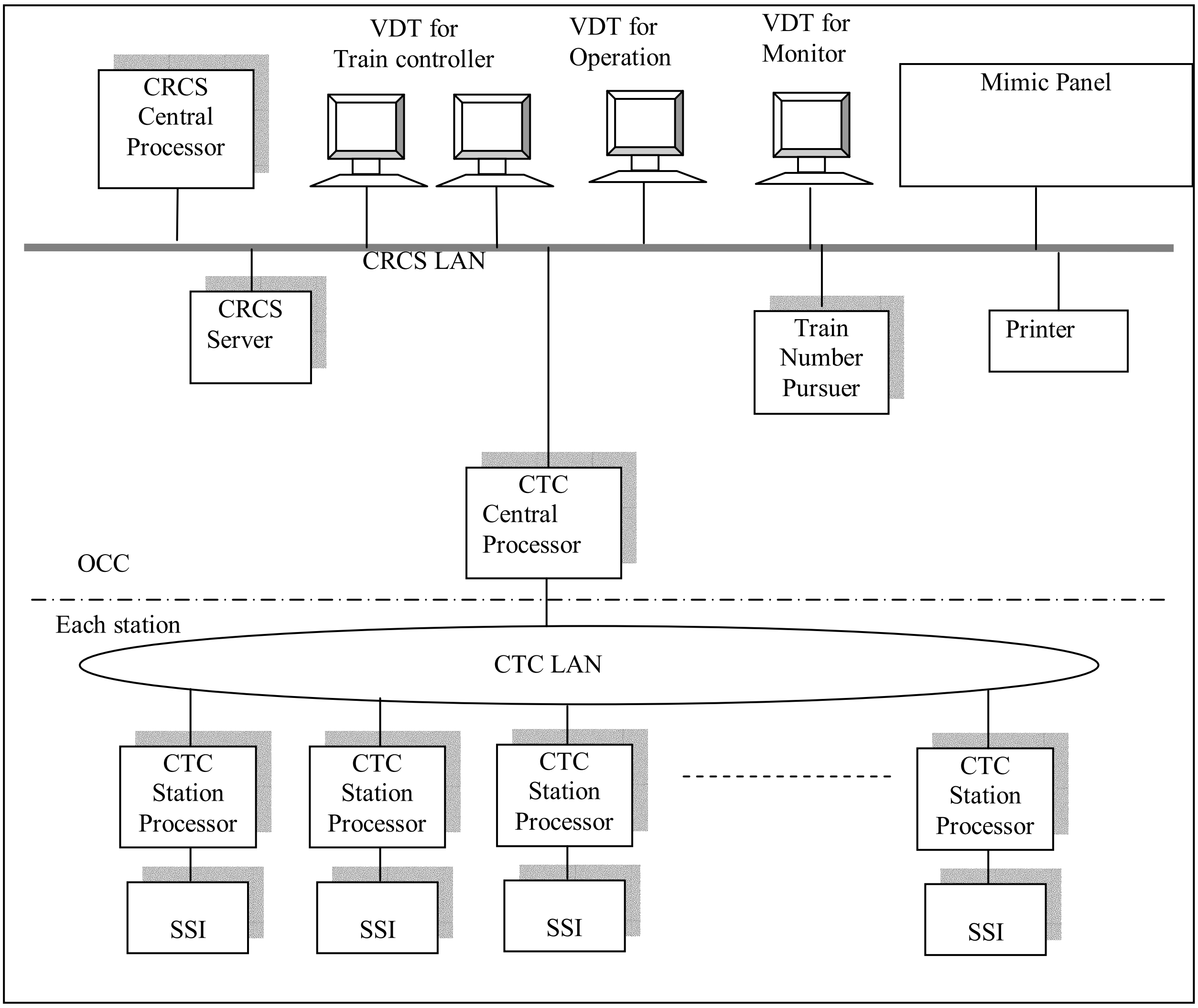


Figure 8-20 Configuration of CRCS (Computerized Route Control System) and CTC

(1) CTC Station Processor

CTC Station Processor interfaces to Interlocking system installed at each station and transmits train location information, point position information signal aspect information, and so on to CTC Central Processor on real time and also transmits the route setting information from CTC Central Processor to Interlocking system at each station.

If Micro Balise is installed in the block section, train ID information from interrogator is transmitted to OCC via CTC system.

(2) CTC Central Processor

CTC Central Processor transmits the information from CTC station Processor in each station to CRCS and transmits the route setting information from CRCS to CTC Station Processor.

Besides CTC Central Processor controls the route setting mode.

The hierarchy of route setting is shown in Figure 8-21.

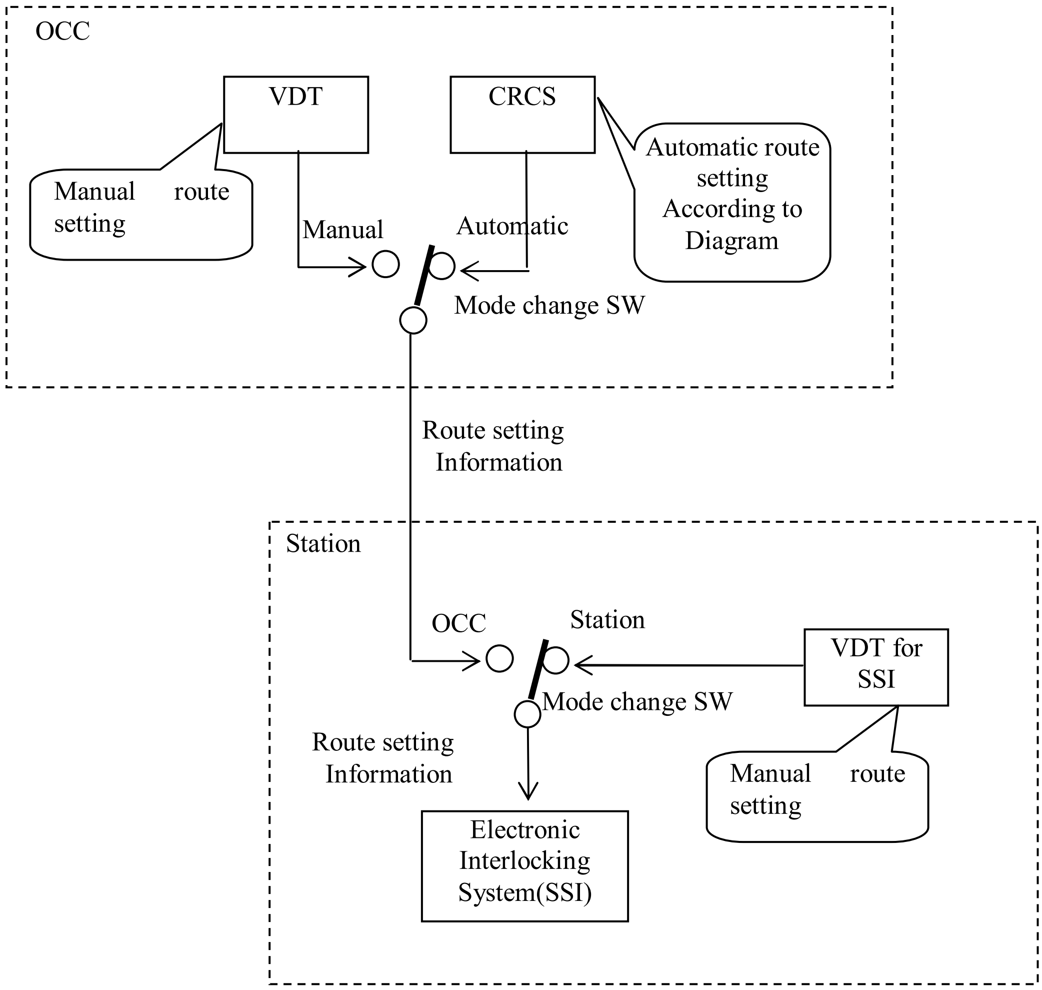


Figure 8-21 Hierarchy route setting system

(3) Mimic Panel

Mimic Panel is large scale Panel and LED type to overview the condition of all line for DFC and indicates the train location, train number, signal aspect, point position, traction power condition and so on.

There are two type of this panel. One is Hardware LED type and the other is Projector type.

The hardware type is recommended because of clear visible.

(4) VDT for operation

VDT for operation is used to input Freight schedule diagram and to modify this diagram for increasing the number of trains or canceling train. Besides it is possible to modify the train number.

(5) VDT for train controller

Divided graphic panel divided to many screens is indicated on this VDT. Monitoring this VDT, train controllers command to the crews. Normally train controller does not set route because of automatic route setting but it is possible to set route from this VDT.

(6) CRCS Central Processor

This Processor output the route setting information for home signal or departure signal to the CTC central processor, judging from diagram, clock data, train location and train number

This system is hot-standby duplex system.

(7) Train Number Pursuer

This system manages the train number location pursing the running train based on the starting train number from the terminal.

This system is provided to maintain the traffic operation when the CRCS experiences failure.

Because the train numbers and train locations are indispensable for traffic operation.

If this system gains the train ID from Micro Balise, the reliability of the train number will be higher with checking this information.

(8) VDT for Monitor

This VDT monitors the condition of CRCS, CTC Central/Station Processor and Train Number Pursuer and failure information is provided to the staff when abnormal.

(9) Printer

This Printer outputs train operation recode and graphical diagram.

(10) CRCS sever

This sever stores the Diagram Data Base, common information using each devices connected to LAN, train operation record, monitoring data of each device and so on.

8.10.7 Hardware Configuration of Monitoring System of Telecommunication and Signaling Devices

The telecommunication and signaling devices should be maintenance-free as much as possible. In the event of any malfunction, in order to minimize the interference to the train operation, a maintenance system and a monitoring facilities are required to support the maintenance tasks.

The flow of the tasks are as follows:

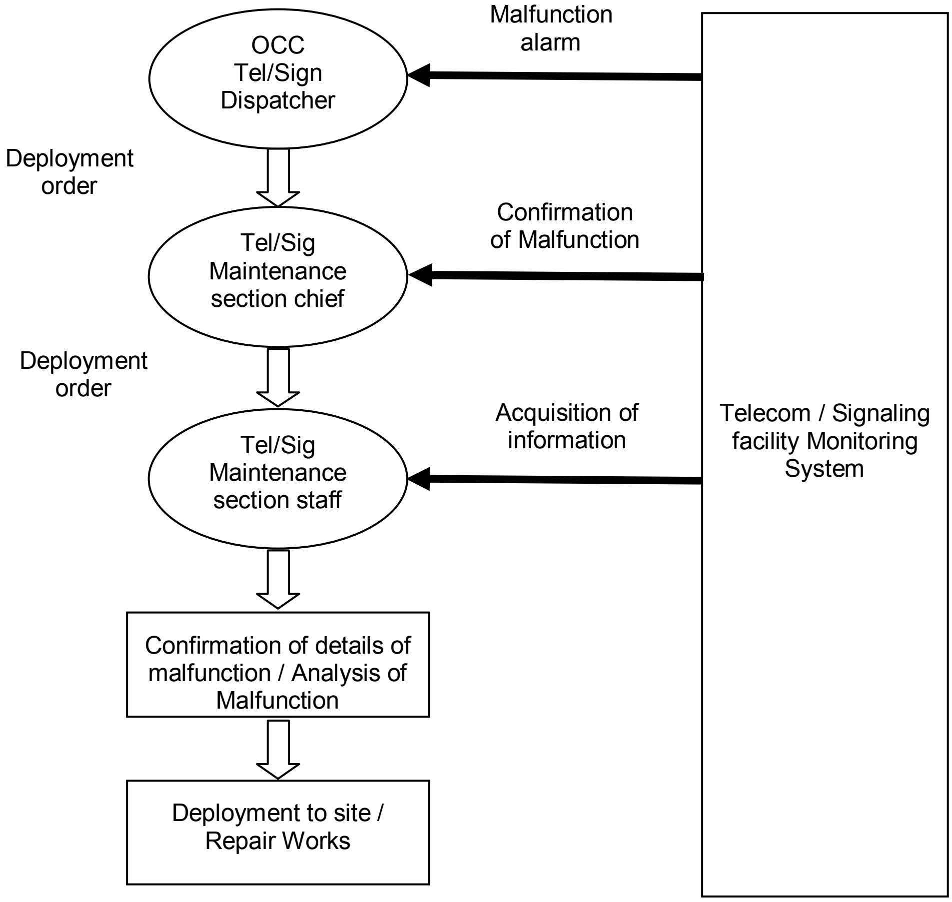


Figure 8-22 Workflow of the Repair Work

The monitoring system supporting the maintenance system requires the following function.

1) Instantaneous reporting function in event of malfunction
2) Information provision function for the early investigation of cause and restoration
3) Data acquisition function for preventive maintenance

In order to realize these functions, equipment monitoring devices, that would monitor the performance and malfunction, shall be installed at OCC and at the maintenance base.