5-3 Basic Train Operation Plan

5-3-1 Premises

The premises for the train operation plan are as shown below.

(1) Train type, operation speed, hauling tonnage and traction type.

Table 5.3.1-1 Train Type, Operation Speed, Hauling Tonnage and Traction Type

Train	Max. speed (km/h)	Hauling tonnage (t)	No. of coaches	Traction	Coach
Long-distance Exp.	160	700	18	High-speed E.L x 2	High-speed coach
Super Exp.	250	865	16	EMU (6M10T)	

(2) Number of passengers per train

Table 5.3.1-2 Number of passenger per Train

Train	No. of passengers
L. Exp.	*1 1,090
S. Exp.	*2 1,560

*1: Approximately 200 passenger capacity will be added to the 880 passenger carrying capacity of the current Rajdhani Express.

*2: The number of passengers of the S. Express Train is assumed to be 1,560.

(3) Loading factor

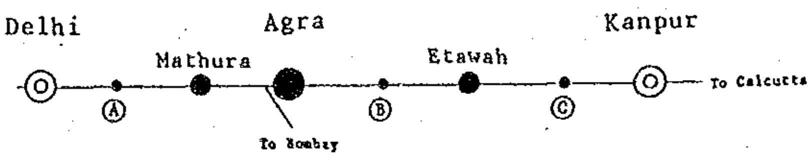
100 percent.

(4) Station

Two kinds of S. Exp. Trains, ⓐ and ⓑ, will be set up based on the patterns of stopping at stations.

Table 5.3.1-3 Train Type and Stopping Station

Train	Maximum speed (km/h)	No. of coaches	carrying capacity	Stopping stations		
				For passenger handling		For train overtaking
L. Exp.	160	18	1,090	Delhi Agra Kanpur		Mathura Etawah Ⓐ Ⓑ Ⓒ
S. Exp.	250	16	1,560	ⓐ	Delhi Agra Kanpur	—
				ⓑ	Delhi Mathura Agra Etawah Kanpur	



(5) Stopping time

o L. distance (L) Express train .... 5 minutes

o S. Express train

- at Agra .... 5 minutes
- at other stations .... 2 minutes

(6) Margin time

20 percent of the running time.

(7) Time for maintenance work

Four hours at night is reserved for maintenance work, for both up and down tracks.

(8) Run-through train speed at the station

None

(9) Operation route of L. Express train

The L. Express Train run into/from the existing line at Agra or Kanpur stations.

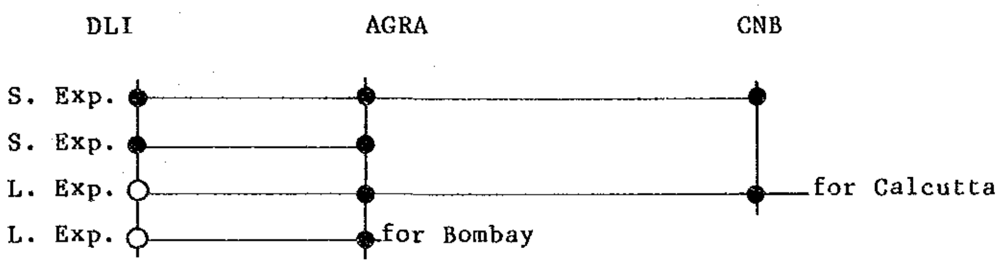


Fig. 5.3.1-1 Operation Route of Super Express and L. Express Trains

(10) Exchange of locomotive of L. Express train

The high-speed locomotives of the L. Exp. train is changed to a conventional locomotive at Kanpur and Agra Station.

5-3-2 Conditions for the train operation plan

(1) Transport demand

The cross sectional transport demand between major stations is forecasted as follows.

Table 5.3.2-1 Cross Sectional Transport Demand by Year and Fare Increase Rate (The New Corridor)

(thousand/day)

Year	UP	Train	DLI MTJ AGRA ETW CNB			
2000	0	S	202.5	195.7	163.9	162.3
		L	8.1	8.1	2.1	2.1
		T	210.6	203.3	166.0	164.4
	25	S	146.4	141.1	117.4	117.1
		L	11.4	11.4	4.0	4.0
		T	157.8	152.5	121.4	121.1
	50	S	95.9	91.6	73.9	73.9
		L	15.8	15.3	6.5	6.5
		T	111.2	106.9	80.4	80.4
	75	S	62.0	58.0	43.6	44.0
		L	17.2	17.2	7.8	7.8
		T	79.2	75.2	51.4	51.8
	100	S	41.9	38.2	26.0	26.7
		L	17.4	17.3	7.9	7.9
		T	59.3	55.5	33.9	34.6
2005	0	S	254.7	246.1	206.2	204.2
		L	9.7	9.7	2.5	2.5
		T	264.4	255.8	208.7	206.7
	25	S	184.1	177.5	147.6	147.2
		L	13.6	13.6	4.8	4.8
		T	197.7	191.1	152.4	152.0
	50	S	122.7	115.3	92.9	92.9
		L	18.2	18.2	7.7	7.7
		T	140.9	133.5	100.6	100.6
	75	S	78.0	73.0	54.9	55.3
		L	20.5	20.5	9.3	9.3
		T	98.5	93.5	64.2	64.6
	100	S	52.8	48.0	32.7	33.6
		L	20.7	20.7	9.4	9.4
		T	73.5	68.7	42.1	43.0
2010	0	S	320.4	309.6	259.4	256.9
		L	11.6	11.6	3.0	3.0
		T	332.0	321.2	262.4	259.9
	25	S	231.7	223.3	185.7	185.2
		L	16.2	16.2	5.7	5.7
		T	247.9	239.5	191.4	190.9
	50	S	154.4	145.0	116.9	116.9
		L	21.7	21.7	9.2	9.2
		T	176.1	166.7	126.1	126.1
	75	S	98.1	91.8	69.1	69.0
		L	24.5	24.5	11.1	11.1
		T	122.6	116.3	80.2	80.1
	100	S	66.4	60.4	41.2	42.3
		L	24.7	24.7	11.2	11.2
		T	91.1	85.1	52.4	53.5
2015	0	S	405.0	391.4	327.8	324.7
		L	13.8	13.8	3.6	3.6
		T	418.8	405.2	331.4	328.3
	25	S	292.8	282.2	234.7	234.1
		L	19.3	19.3	6.8	6.8
		T	312.1	301.5	241.5	240.9
	50	S	191.8	183.3	147.8	147.7
		L	26.0	25.9	11.0	11.0
		T	217.8	209.2	158.8	158.7
	75	S	124.0	116.0	87.3	88.0
		L	29.2	29.2	13.3	13.3
		T	153.2	145.2	100.6	101.3
	100	S	83.9	76.4	52.1	53.4
		L	29.5	29.5	13.4	13.4
		T	113.4	105.9	65.5	66.8

Note: 1 Up means fare increase of 0, 25, 50, 75 and 100%.
2 S, L and T in the "Train" Column are Super Express Train, Long-distance Express Train and Total, respectively.

Table 5.3.2-2 Cross Sectional Transport Demand by Year and Fare Increase Rate (The Section)

Item	Year	UP	Train	DLI–GZB	GZB–KRJ	KRJ–ALJN	ALJN–TDL	TDL–SKB	SKB–ETW	ETW–CNB
Pass (thousand /day)	2000	0	E/M		77.9	54.4	32.0	21.1	29.5	27.5
			ℓ		13.9	8.4	7.2	8.3	4.2	6.5
			T	210.0	91.8	62.8	39.2	29.4	33.7	34.0
		25	E/M		81.5	61.1	41.7	31.5	39.8	37.9
			ℓ		13.9	8.4	7.2	8.3	4.2	6.5
			T	210.3	95.4	69.5	48.9	39.8	44.0	44.4
		50	E/M		87.0	68.8	51.6	42.1	50.5	47.9
			ℓ		13.9	8.4	7.2	8.3	4.2	6.5
			T	213.4	100.9	77.2	58.8	50.4	54.7	54.4
		75	E/M		92.7	75.9	60.3	51.2	59.5	56.2
			ℓ		13.9	8.4	7.2	8.3	4.2	6.5
			T	217.8	106.6	84.3	67.5	59.5	63.7	62.7
		100	E/M		99.8	83.8	69.4	60.7	69.0	65.1
			ℓ		13.9	8.3	7.2	8.3	4.2	6.5
			T	225.9	113.7	92.1	76.6	69.0	73.2	71.6
	2005	0	E/M		93.9	65.5	38.7	25.7	35.4	33.3
			ℓ		15.6	9.4	8.1	9.4	4.8	7.3
			T	250.5	109.5	94.9	46.8	35.1	40.2	40.6
		25	E/M		98.2	73.5	50.3	38.1	47.8	45.7
			ℓ		15.6	9.4	8.1	9.4	4.8	7.3
			T	250.8	113.8	82.9	58.4	47.5	52.6	53.0
		50	E/M		104.8	82.7	62.0	50.8	60.5	57.6
			ℓ		15.6	9.4	8.1	9.4	4.8	7.3
			T	254.6	120.4	92.1	70.1	60.2	65.3	64.9
		75	E/M		111.5	91.1	72.4	61.6	71.3	67.5
			ℓ		15.6	9.4	8.1	9.4	4.8	7.3
			T	259.8	127.1	100.5	80.5	71.0	76.1	74.8
		100	E/M		120.0	100.5	83.3	75.0	82.6	78.1
			ℓ		15.6	9.4	8.1	9.3	4.8	7.3
			T	269.5	135.6	109.9	91.4	84.3	87.4	85.4
	2010	0	E/M		113.0	78.8	46.7	31.3	42.6	40.2
			ℓ		17.6	10.6	9.1	10.6	3.4	8.2
			T	298.9	130.6	89.4	55.8	41.9	48.0	48.4
		25	E/M		118.2	88.3	60.5	46.1	57.3	55.0
			ℓ		17.6	10.6	9.2	10.5	5.4	8.2
			T	299.2	135.8	98.9	69.7	56.6	62.7	63.2
		50	E/M		126.1	99.2	75.2	61.3	72.5	69.2
			ℓ		17.5	10.6	9.2	10.6	5.4	8.2
			T	303.8	143.6	109.8	84.4	71.9	77.9	77.4
		75	E/M		134.1	109.3	86.9	74.2	85.4	81.0
			ℓ		17.6	10.6	9.1	10.5	5.4	8.2
			T	309.9	151.7	119.9	96.0	84.7	90.8	89.2
		100	E/M		144.2	120.5	100.0	87.7	98.9	93.6
			ℓ		17.6	10.6	9.1	10.5	5.4	8.2
			T	321.6	161.8	131.1	109.1	98.2	104.3	101.8
	2015	0	E/M		136.2	94.9	56.4	38.2	51.2	48.5
			ℓ		19.7	11.9	10.3	11.8	6.0	9.3
			T	357.0	155.9	106.8	66.7	50.0	57.2	57.8
		25	E/M		142.4	106.2	73.0	55.7	68.8	66.2
			ℓ		19.7	11.9	10.3	11.9	6.0	9.3
			T	357.4	162.1	118.1	83.3	67.6	74.8	75.8
		50	E/M		151.8	119.3	89.7	73.9	87.0	83.2
			ℓ		19.7	11.9	10.3	11.9	6.0	9.3
			T	362.8	171.5	131.2	100.0	85.8	93.0	92.5
		75	E/M		161.4	131.3	104.4	89.3	102.4	97.3
			ℓ		19.7	11.9	10.3	11.9	11.9	9.3
			T	370.2	181.1	143.2	114.7	101.2	114.3	106.6
		100	E/M		173.5	144.7	120.0	105.4	118.5	112.4
			ℓ		19.7	11.9	10.3	11.9	6.0	9.3
			T	384.1	193.2	156.6	130.3	117.3	124.5	121.7
Freight (thousand ton/ day)	2000	—	—	151.5		148.6	173.4		178.6	181.2
	2005	—	—	184.3		180.9	211.0		217.4	220.5
	2010	—	—	224.3		220.1	256.7		264.5	268.3
	2015	—	—	272.8		267.7	312.2		321.7	326.3

Note: 1. Up means fare increase of 0, 25, 50, 75 and 100%.
2. E/M, ℓ and T in the "Train" Column are Express/Mail, Local Train and Total, respectively.
3. Increase in local passengers is calculated as an average of 2.5% per year based on the figure in 1985.

(2) Traveling time and commercial speed of the New Corridor

1) Premises for the calculation of the travel time

. Track conditions

There will be no operation speed restriction for high speed train operation at 250 km/h, except for the speed restriction of approx. 70 km/h required in branching-off the turnouts.

. Station intervals

The station intervals are assumed as follows. (See Fig. 5.3.2-1)

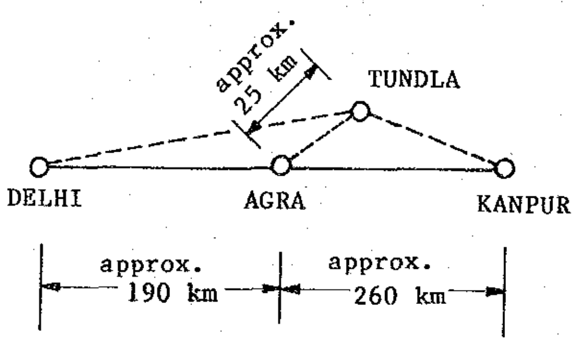


Fig. 5.3.2-1 Station Intervals

. Operating speed

A speed 5 km/h lower than the maximum operating speed is assumed as the train operating speed.

. Distance and time for acceleration and deceleration

The acceleration and deceleration distance and time are calculated applying the assumed performance curves of Rolling Stock.

2) Travelling time and commercial speed

In calculating the travelling time, waiting time for the passing train are excluded.

Table 5.3.2-3 Travelling Time and Commercial Speed

Section / Travelling time & Commercial speed / Train	DLI - AGRA		AGRA - CNB		DLI - CNB	
	Travelling time (min)	Commercial speed (km/h)	Travelling time (min)	Commercial speed (km/h)	Travelling time (min)	Commercial speed (km/h)
L. Exp.	100	120	130	120	235	117
S. Exp. ⓐ	65	185	85	184	155	178
S. Exp.. ⓑ	72	167	92	170	169	163

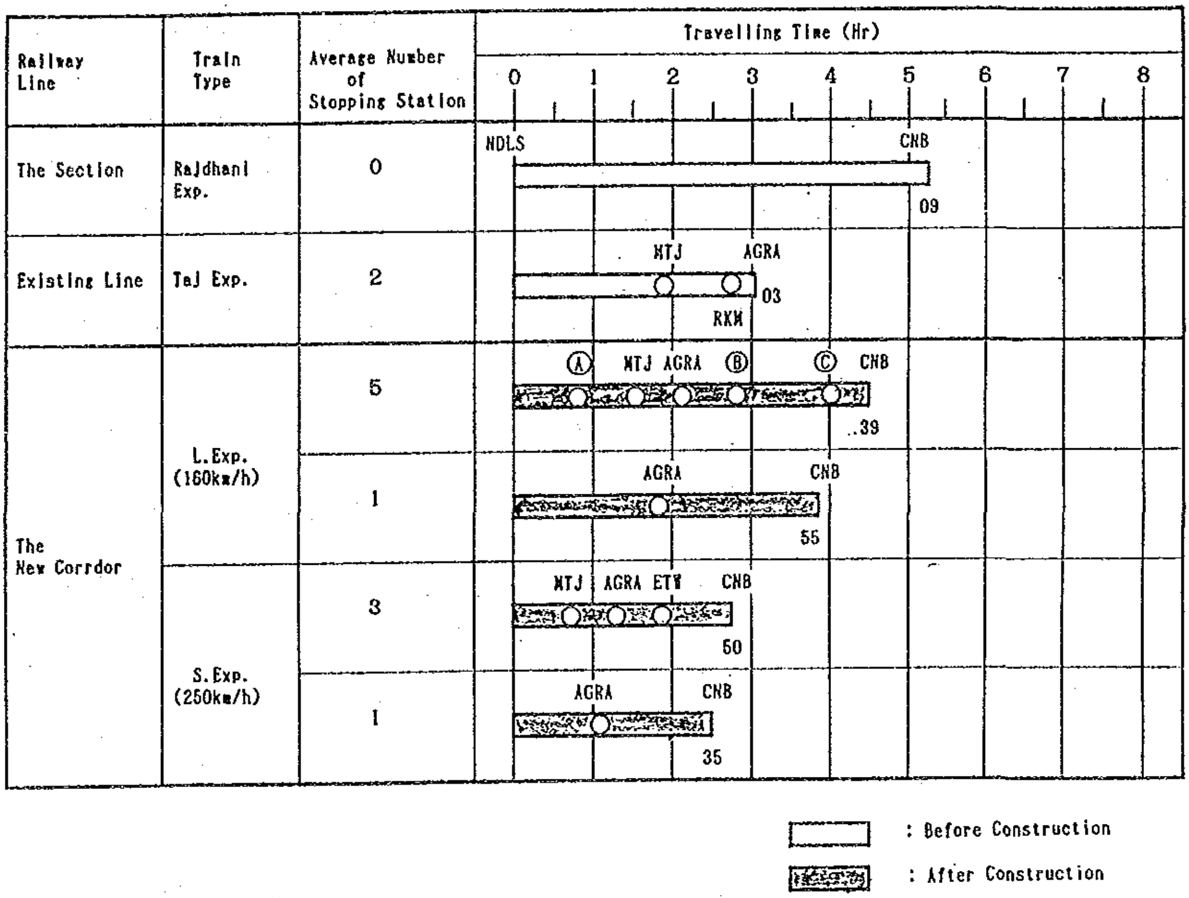


Fig. 5.3.2-2 Traveling Time

5-3-3 Transport planning

The number of trains needed between major stations is calculated according to the demand forecast and the prerequisite of the aforementioned basic operation plan.

Looking at the New Corridor, as shown in Fig. 5.3.3-1, the number of trains is greatly affected by the fare: the cheaper the fare, the greater the number of trains. That is, 0% fare increase on the Super Exp. will make the track capacity saturated by 2005, while 2010 will be the year of saturation with a 25% fare increase. At over a 50% fare increase, the track capacity is expected to meet the traffic demand till 2015 or later.

The ratio of L. Exp. trains to the total number of trains will become greater as the fare of the Super Exp. trains rises.

Observing the Section, as shown in Fig. 5.3.3-2, the number of trains decreases as the fare of the New Corridor becomes less expensive, since more passengers will transfer to the New Corridor. The difference, however, is relatively small, and the year when the train number reaches the saturation level is expected to be 2003 with a 100% fare increase, and 2006 with a 0% fare increase.

Section-wise, as shown in Appendix 2-8, the greatest number of passenger trains is found in GZB - KRJ, and that of freight trains is found in ALJN - TDL.

In this transport plan, a prerequisite should be that after the New Corridor construction the Section be used mainly for freight transport, covering the freight traffic demand till 2010 at the earliest.

Therefore, the differential between the number of freight trains in 2010 and the track capacity will be adopted as the number of passenger trains after 2000.

Since there is an extremely great demand of passengers in the DLI/NDLS - ALJN Section (130 km) compared with other sections, intermediate distance Exp. trains shall be operated in this section.

The cross-section traffic between major stations is as shown in Fig. 5.3.3-3. According to this, the number of passengers in 2010 is expected to become about 7 and 6 times greater than in 1985 at 25% and 50% fare increases, respectively. As for freight, the expected growth is 3.7 times for the same period.

The number of trains of each kind by year and by fare rate is shown in Table 5.3.3-1 and Table 5.3.3-2. For details, refer to Appendix 2-9.

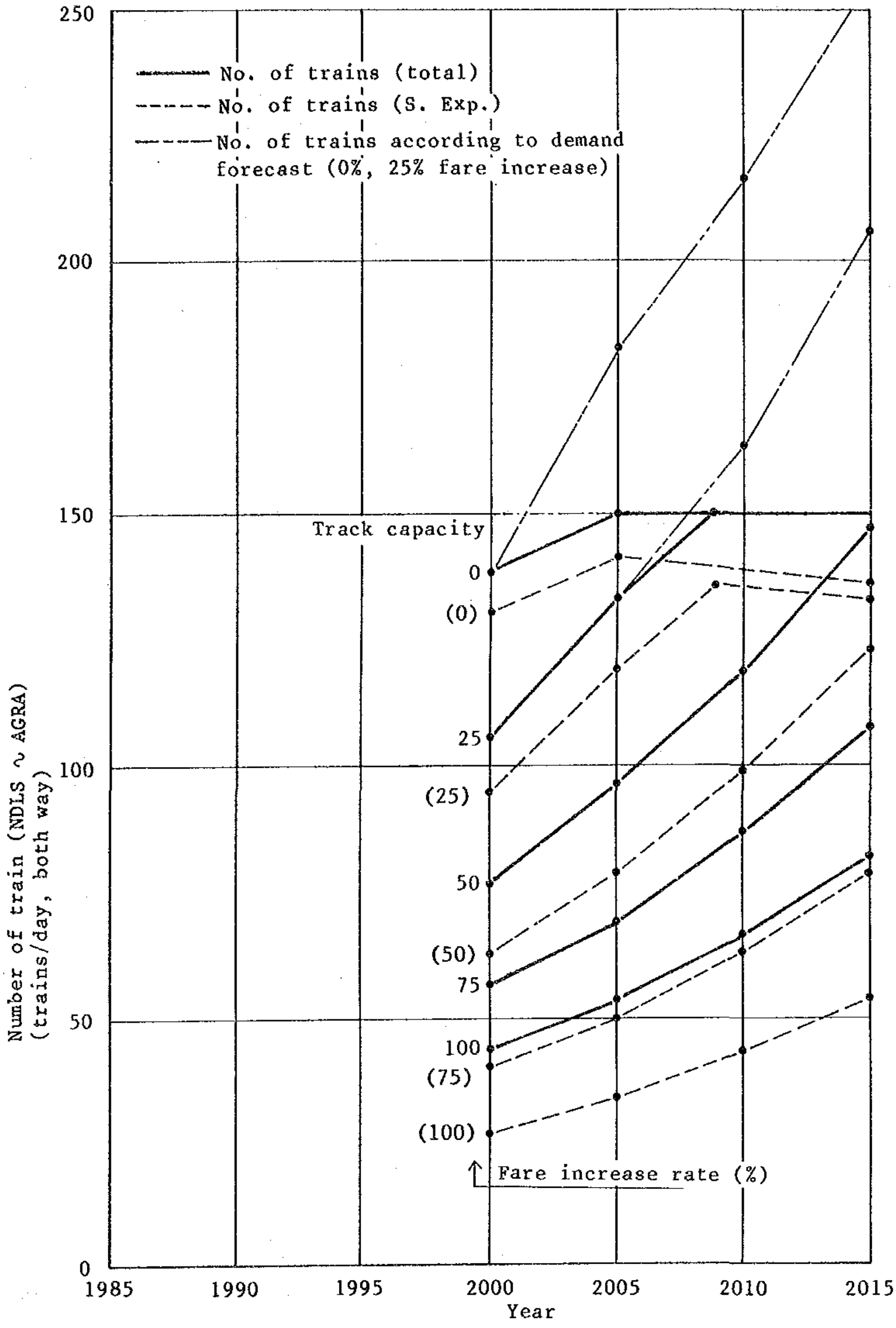


Fig. 5.3.3-1 Number of Train by Year and Fare (The New Corridor)

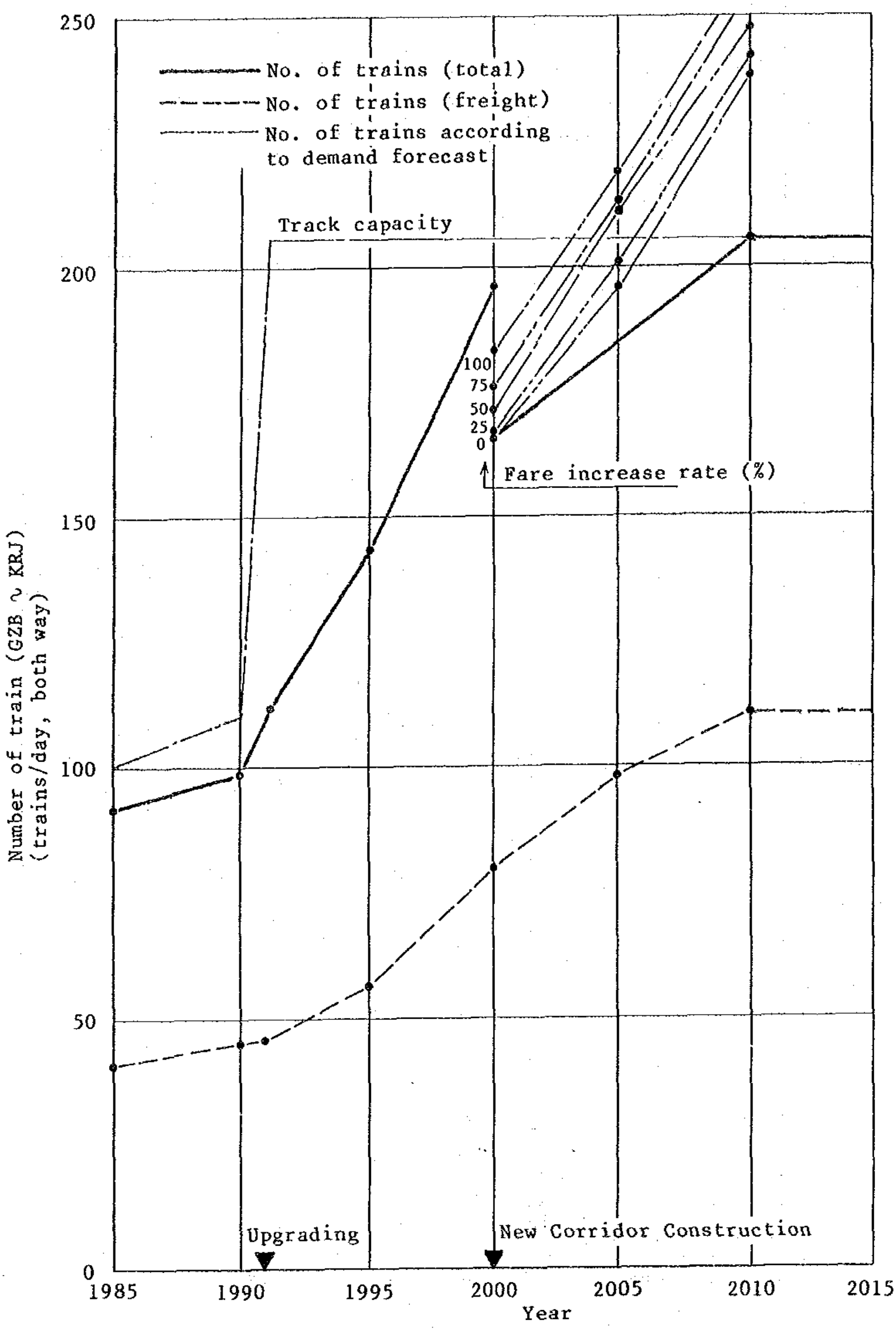


Fig. 5.3.3-2 Number of Train by Year and Fare (The Section)

Table 5.3.3-1 Number of Trains by Year and Fare on the New Corridor (Delhi - Kanpur)

UP	Year	Train	DLI – AGRA	AGRA – CNB
0	2000	S	130	105
		L	8	2
		T	138	107
	2005	S	141	133
		L	9	3
		T	150	136
	2010	S	139	139
		L	11	3
		T	150	142
	2015	S	137	137
		L	13	4
		T	150	141
25	2000	S	94	76
		L	11	4
		T	105	80
	2005	S	119	95
		L	13	5
		T	132	100
	2010	S	141	119
		L	15	6
		T	156	125
	2015	S	138	138
		L	18	7
		T	156	145
50	2000	S	62	48
		L	14	6
		T	76	54
	2005	S	79	60
		L	17	7
		T	96	67
	2010	S	99	75
		L	20	9
		T	119	84
	2015	S	123	95
		L	24	10
		T	147	105
75	2000	S	40	29
		L	16	8
		T	56	37
	2005	S	50	36
		L	19	9
		T	69	45
	2010	S	63	45
		L	23	11
		T	86	56
	2015	S	80	57
		L	27	13
		T	107	70

UP	Year	Train	DLI – AGRA	AGRA – CNB
100	2000	S	27	17
		L	16	8
		T	43	25
	2005	S	34	22
		L	19	9
		T	53	31
	2010	S	43	27
		L	23	11
		T	66	38
	2015	S	54	35
		L	27	13
		T	81	48

Notes:
1. The number of trains is the total of up and down per day.
2. S, L and T in the "train" Column represent the Super Express, L.Express and total, respectively.
3. The hatched numbers show decreased numbers of trains due to the shortage of track capacity which cannot meet the demand.

Table 5.3.3-2 Number of Trains by Year and Fare on the Section (GZB - CNB)

UP	Year	Train	GZB-KRJ	KRJ-ALJN	ALJN-TDL	TDL-SKB	SKB-ETW	ETW-CNB
0	2000	P	84	64	64	42	34	36
		F	78	84	97	88	90	90
		M	2	2	2	4	4	4
		T	164	150	141	134	128	130
	2005	P	86	73	48	45	39	41
		F	96	102	118	108	110	110
		M	2	2	2	4	4	4
		T	184	177	168	157	153	155
	2010 ~ 15	P	86	80	55	51	47	48
		F	118	124	144	131	133	133
		M	2	2	2	4	4	4
		T	206	206	201	186	184	185
25	2000	P	86	70	51	49	43	45
		F	78	84	97	88	90	90
		M	2	2	2	4	4	4
		T	166	156	150	141	137	139
	2005	P	86	80	58	56	50	52
		F	96	102	118	108	110	110
		M	2	2	2	4	4	4
		T	184	184	178	168	164	166
	2010 ~ 15	P	86	80	60	64	60	62
		F	118	124	144	131	133	133
		M	2	2	2	4	4	4
		T	206	206	206	199	197	199
50	2000	P	86	76	60	58	52	54
		F	78	84	97	88	90	90
		M	2	2	2	4	4	4
		T	166	162	159	150	146	148
	2005	P	86	80	60	67	61	63
		F	96	102	118	108	110	110
		M	2	2	2	4	4	4
		T	184	184	180	179	175	177
	2010 ~ 15	P	86	80	60	71	65	67
		F	118	124	144	131	133	133
		M	2	2	2	4	4	4
		T	206	206	206	204	200	202
75	2000	P	86	80	60	66	60	62
		F	78	84	97	88	90	90
		M	2	2	2	4	4	4
		T	166	166	159	158	154	156
	2005	P	86	80	60	71	65	67
		F	96	102	118	108	110	110
		M	2	2	2	4	4	4
		T	184	184	180	183	179	181
	2010 ~ 15	P	86	80	60	71	65	67
		F	118	124	144	131	133	133
		M	2	2	2	4	4	4
		T	206	206	206	206	202	204
100	2000	P	86	80	60	71	65	67
		F	78	84	97	88	90	90
		M	2	2	2	2	2	2
		T	166	166	159	163	159	161
	2005	P	86	80	60	71	65	67
		F	96	102	118	108	110	110
		M	2	2	2	4	4	4
		T	184	184	180	183	179	181
	2010 ~ 15	P	86	80	60	71	65	67
		F	118	124	144	131	133	133
		M	2	2	2	4	4	4
		T	206	206	206	206	202	204

Notes:
1. The number of train is the total of up and down trains per day.
2. P, F, M and T in "train" Column represent the Passenger, Freight Miscellaneous Train and Total, respectively.
3. The hatched numbers areas show the number of passenger trains decreased below the demand to meet the freight traffic demand till 2010.

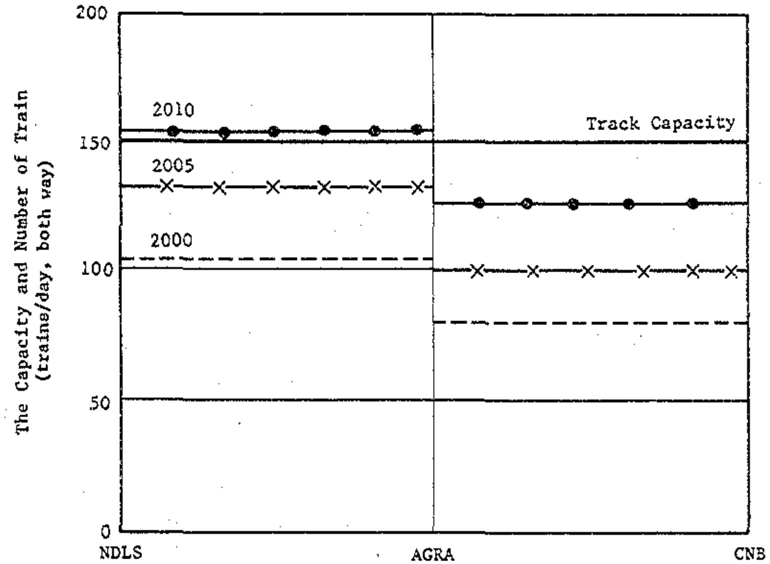


Fig.5.3.3-3 Yearly Number of Trains and Track Capacity (The New Corridor) (For a Fare Increase Rate of 25%)

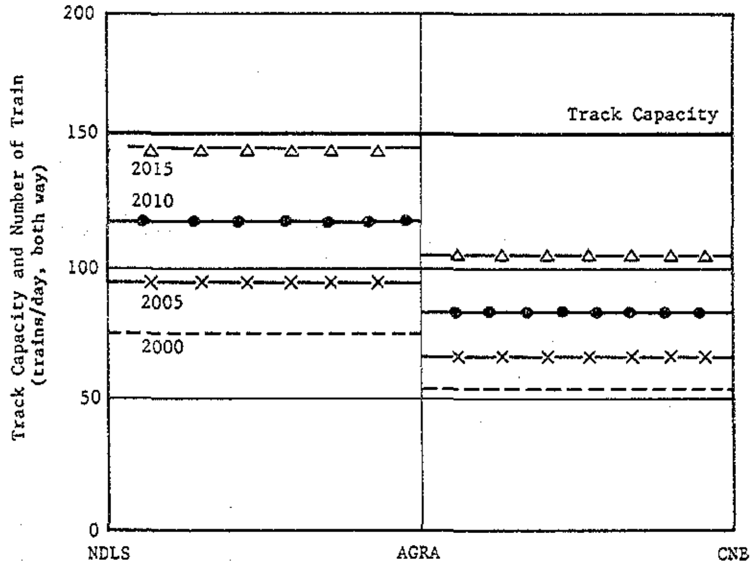


Fig. 5.3.3-5 Yearly Number of Trains and Track Capacity (The New Corridor) (For a Fare Increase Rate of 50%)

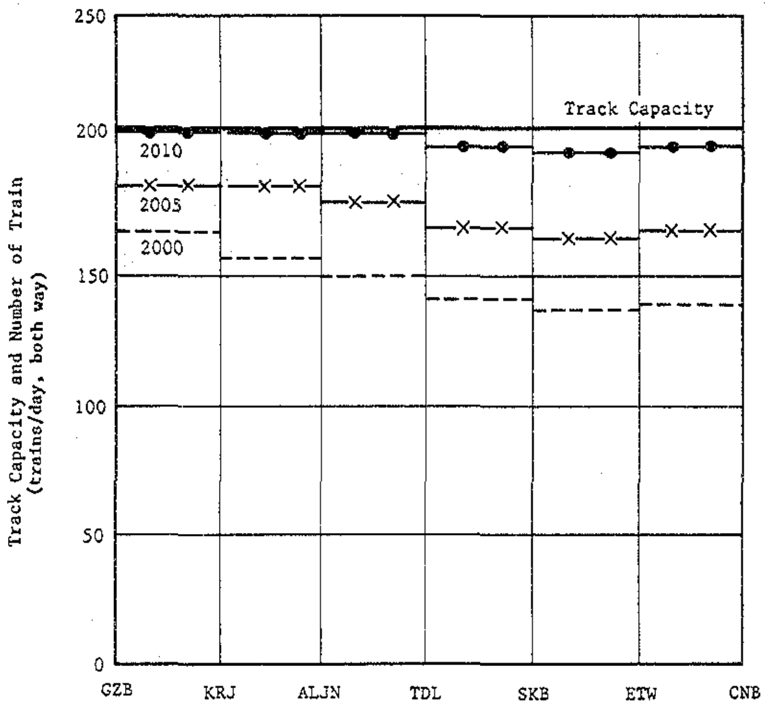


Fig. 5.3.3-4 Yearly Number of Trains and Track Capacity (The Section) (For a Fare Increase Rate of 25%)

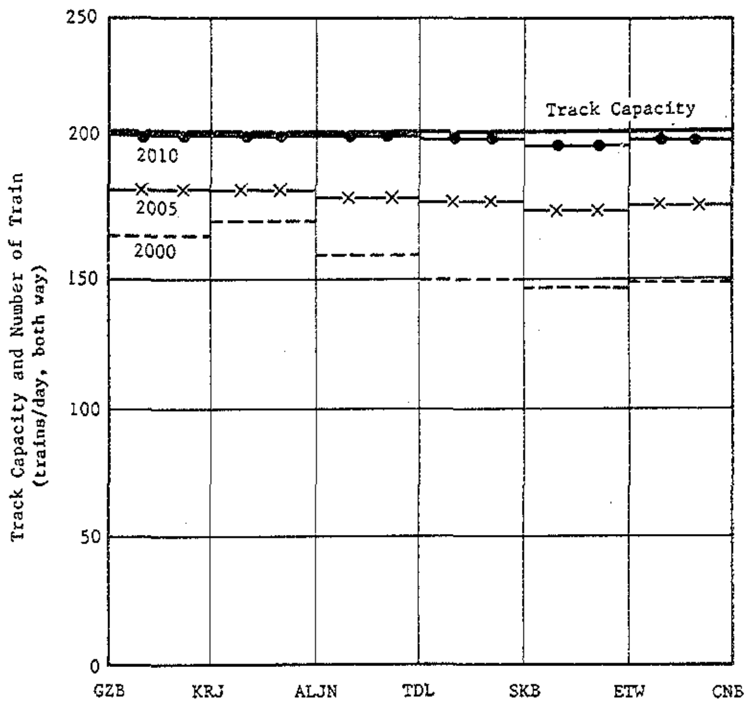


Fig. 5.3.3-6 Yearly Number of Trains and Track Capacity (The Section) (For a Fare Increase Rate of 50%)

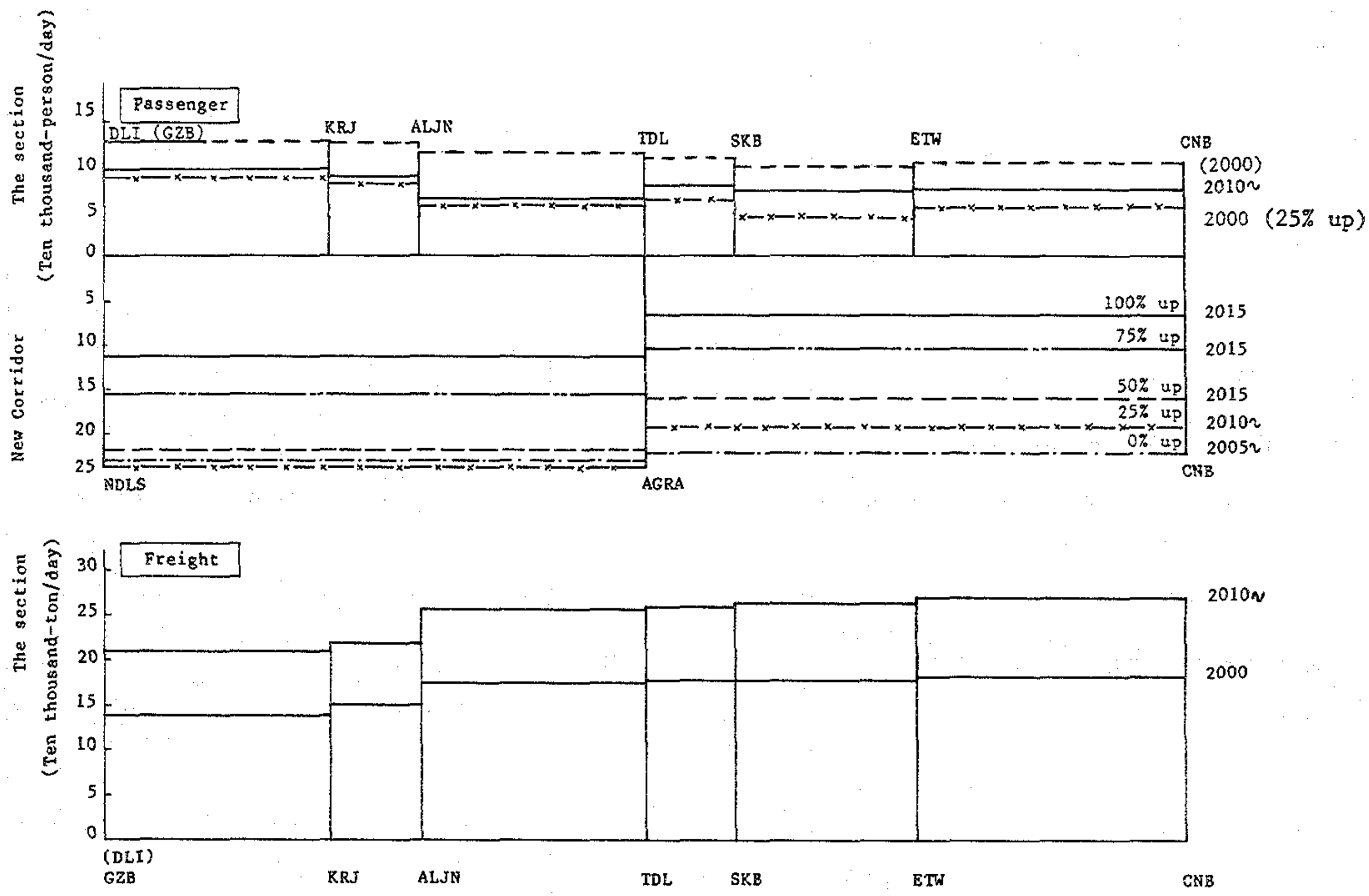


Fig. 5.3.3-7 Cross Sectional Traffic of the New Corridor and the Section

5-4 Rolling Stock

High speed rolling stock (250 km/h) for the New Corridor will be designed based on the forecasted traffic conditions and natural environments, and also depending on comparative studies with respect to technology and economy regarding the other high speed trains in the world.

5-4-1 Basic performance

(1) Track conditions

1) Grade : less than 5/1,000

2) Sharpest curve: 4,000 radius

(2) Operating conditions

1) The train operating conditions are shown in Table 5.4.1-1.

Table 5.4.1-1 Operating Conditions

Max. speed (km/h)	Carrying capacity (Passengers/train)	Train length (m)
250	Approx. 1,400	Approx. 400

2) Train traction system

From the comparative study results mentioned below regarding the EMU train and the EL train, the EMU traction system will be taken.

- The EMU train of decentralized power system is superior in acceleration and deceleration.

  For this reason, EMUs are suitable and advantageous for use in small-distance operation between stations as well as frequent train service.

- In the case of EMUs, the higher the composition share of motor coaches, the bigger the electric brake force of regenerative brakes, rheostatic brakes, eddy current brakes, etc, allowing faster deceleration and smaller brake disc and lining replacement expenses.

- The EMU with light axle weight due to decentralized power system has a less adverse effect on the track, thus reducing the track maintenance cost. A light axle weight, on the other hand, is less subject to counter-shocks from the track, and it is advantageous from the viewpoint of preventing cracking on the truck frame.

  In case of EL, limited axle weight and motor-mounting space will confine the increase in the traction power per axle.

- In case of EMU, high acceleration will shorten the travelling time, and no locomotive changing work is needed at terminal stations.

- In case of the EMU, disturbance of the train operation due to trouble of one power unit, can be minimized.

- The EMU can flexibly comply with the change of number of passengers by changing the M/T ratio and the number of coaches, while the EL with the fixed power output makes it difficult.

- From the viewpoint of platform occupancy and facilities for shunting at terminal stations, the EMU is more advantageous.

- Procurement cost and maintenance cost of the EMU train is more expensive than those of the EL train. (Usually approx. 1.3 times.)

3) Miscellaneous

The high-speed EL for Long distance Express trains to operate on the New Corridor will be equipped with an ATC system.

5-4-2 Principal particulars and characteristics

As a result of the comparative study on the high-speed trains of various countries, the 100-series Shinkansen train which is the most superior in both procurement cost and energy consumption per passenger shall be chosen as the standard for the study.

Ratio of 100-series Shinkansen train to TGV:
Rolling stock procurement cost = 60 : 100
Energy consumption = 65 : 100

High-speed trains of various countries are compared on the various aspects in the Appendix 3-4.

A proposal for Super Express trains is shown in Table 5.4.2-1. This proposal has been prepared based on the 100-Series Shinkansen EMU. To reduce the procurement cost and the maintenance cost per passenger, the number of motor coaches is minimized, and the number of seats is increased. In addition, new technologies such as 3-phase asynchronous motor and light alloy body, etc., are employed.

The 6M10T train in the proposal has the minimum M/T ratio with a raised traction motor output, and its motor coaches are designed to accommodate passengers.

The 2M14T train is of a push-pull system with two ELs. And considering the high speed train operation at 250 km/h, every vehicle will be of airtight structure.

Table 5.4.2-1 Particulars of S. Exp. Trains on the New Corridor (Tentative plan)

Condition {Straight line, Level}

Item \ Composition	6M10T (Normal Type)	2M14T (Push-pull Type)
Max. speed (km/h)	250	250
Carrying capacity (pass./train)	1,560 (97.5 × 16)	1,425 (101.8 × 14)
Train length (m)	400	400
Rated power (kW)	7,920 (330 × 4 × 6)	7,000 (875 × 4 × 2)
Train weight loaded (ton)	861	851
Axle weight (ton)	15 ~ 12.4	19.5 ∿ 12.4
Acceleration (m/s^2) (at 5 km/h)	0.34	0.33
Deceleration (m/s^2)	0.63	0.45
Power (kW/pass.)	5.08	4.91
(kRs/pass.) Purchasing cost per pass.	80.2	78.3
(kRs/pass./year) Train maintenance cost per pass. per year	2.67	2.69
(mil Rs/year) Track maintenance cost per year 6M10T: 70 trains/day 2M14T: 77 trains/day	90.6	108.7

Comparing both alternatives, no problem is found in the practical performance. In economy, ratios of 6M10T to 2M14T regarding procurement cost, maintenance cost, and track maintenance cost per passenger are as follows.

	(6M10T : 2M14T)
Procurement cost	≒ 102 : 100
Maintenance cost	≒ 99 : 100
Track maintenance cost	≒ 83 : 100

As shown in Table 5.4.2-1, in terms of seat capacity, 6M10T accomodates 1.1 times larger number of passengers than 2M14T. Regarding procurement and maintenance costs per train formation, on the contrary, 6M10T necessitates approximately 1.1 times larger costs than 2M14T. Consequently it can be said that both alternatives are nearly the same in the procurement cost and the maintenance cost. The 6M10T system, however, is considered more preferable for the 250 km/h train, since its lighter axle weight and smaller passing tonnage will permit a lower track maintenance cost by approximately 20 million Rs/year.

The characteristics of these trains are shown as follows.

(1) Speed vs. tractive effort and train resistance curve: (Appendix 3-5)

(2) Acceleration curve: (Appendix 3-6)

(3) Deceleration curve: (Appendix 3-7)

The speed vs. tractive effort curve of 6M10T is based on the coefficient of adhesion between rail and wheel in fine weather.

The system should be so designed that, when the coefficient of adhesion at 80 ~ 240km/h becomes lower owing to rain or something, the control system functions to reduce the tractive effort to prevent wheel slip.

5-4-3 Adoption of new technology

The new technologies adopted to the rolling stock of the New Corridor are shown in Table 5.4.3-1.

Table 5.4.3-1 Adoption of New Technology

Item	Present situation	Upgrading of the Section			The New Corridor	Appendix
		Fast Fr.	L. Exp. (Bo-Bo-Bo/	Bo-Bo)		
3-phase asynchronous motor	×	×	×	○	○	3-12
Regenerative brake	×	×	×	○	○	3-12
Eddy current brake	×	×	×	×	○	3-13
Electromagnetic air brake	○ (EMU)	×	○	○	×	3-10
Continuous controlled brake	×	×	×	×	○	3-14
Flexible type gear coupling	○ (WAM2, WAM3)	○	○	○	○	3-9
Disc brake	×	×	○	○	○	3-11
Thyristor phase control	×	○	○	×	×	
Light alloy body	×	×	○	○	○	3-15
Bolsterless type bogie	×	○	○	○	○	3-8
Information system	×	×	×	×	○	3-16

○: Adopted ×: Not adopted

Details of various new technologies are shown in the Appendix 3-8 to 3-16.
(Thyristor phase control is shown in Page 4-29.)

5-5 Ground Facilities

5-5-1 Track and Structure

(1) Construction standards and standard structures

1) Structure gauge and vehicle gauge

In determining the structure gauge and vehicle gauge, the current Indian Railways standard is applied, with reference to the standard of Japanese Shinkansen Line.

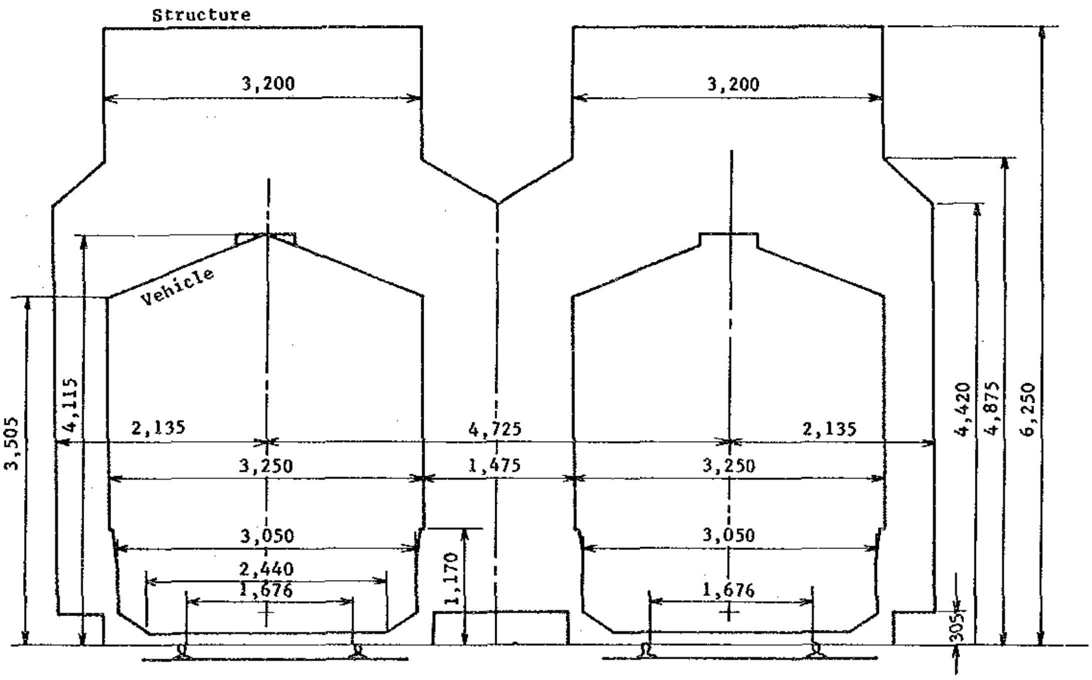


Fig. 5.5.1-1 Structure and Vehicle Gauge

2) Standard structure of railroad formation

The intermediate part of the route will be an embankment at a height of 3.5 meters or more, taking the intersecting agricultural loads and cattle paths into consideration. The railroad formation will be constructed according to the IR standard, but reinforcement of the formation with asphaltic-bitumen concrete will be performed at the surface of the embankment. A maintenance path of more than 1.2 meters width will be arranged throughout the tracks at the left side (or right side) of track on the formation level. Fig. 5.5.1-2 shows the standard cross sectional drawing.

Agricultural road on embankment section is shown in the Appendix 4-12.

The general longitudinal section is shown in Appendix 4-18.

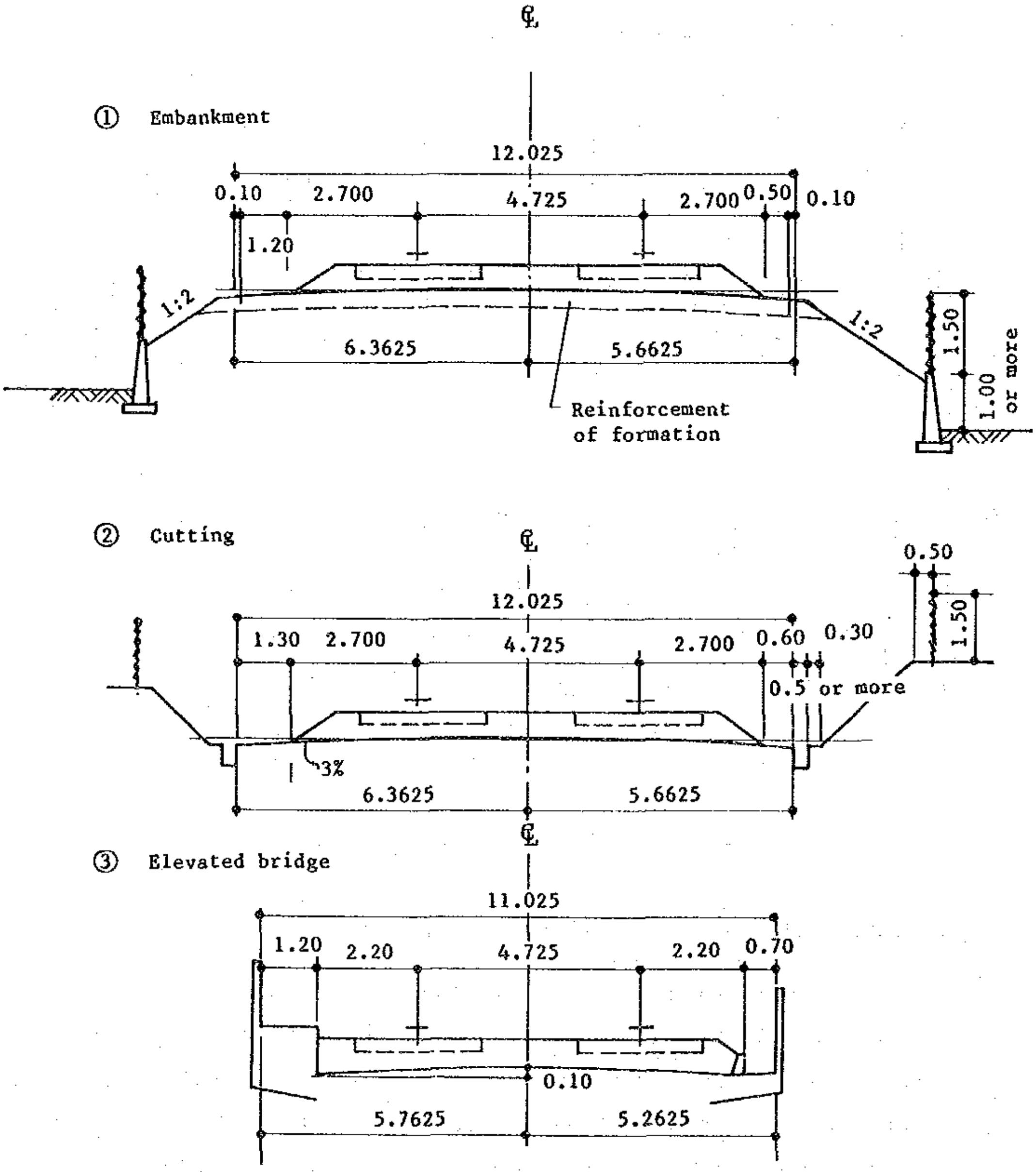


Fig. 5.5.1-2 Standard Profile of Structures

3) Standard of track structure

The track structure of the main track will be as follows:

Rail .... 60 kg, CWR

Sleeper ..... PRC, 1,720/km

Fastening ... Double elastic fastening

Ballast ..... Crushed stone 30 cm or more

Turnout ..... Turnout with movable nose

(2) Station plan

1) New Delhi Station

Arrival/departure loops and platforms will be added in the New Delhi Station yard.

The wagon workshop at the east side of the station will be transferred to another place, and the repair track and washing track facilities will be transferred there, thus securing the space for the new two platforms and 4 arrival/departure loops.

The track layout is shown in the Fig. 5.5.1-3.

2) New Agra Terminal Station

New Agra Station of elevated type will be newly constructed at the north of the current Bilochpura Station. At the station toward New Delhi, a branch line will be constructed to allow the transfer of the L. Exp. Train to/from the conventional line. The elevated station will have 2 platforms and 4 arrival/departure tracks as well as a track layout which permits shuttle operation of the S. Exp. Train. The new station will also be provided with connecting installations for transit to the conventional Bilochpura Station. The Fig. 5.5.1-4 shows the station plan.

For EMU shuttling on the New Agra Station, 2 stabling tracks will be newly prepared at the Agra City Station.

3) New Kanpur Terminal Station

The space for the New Kanpur Station will be ensured by transferring the storage tracks at the south side of the main track in the Juhi Marschalling yard. The structure will be an elevated station of approximately 15 meters height to allow grade

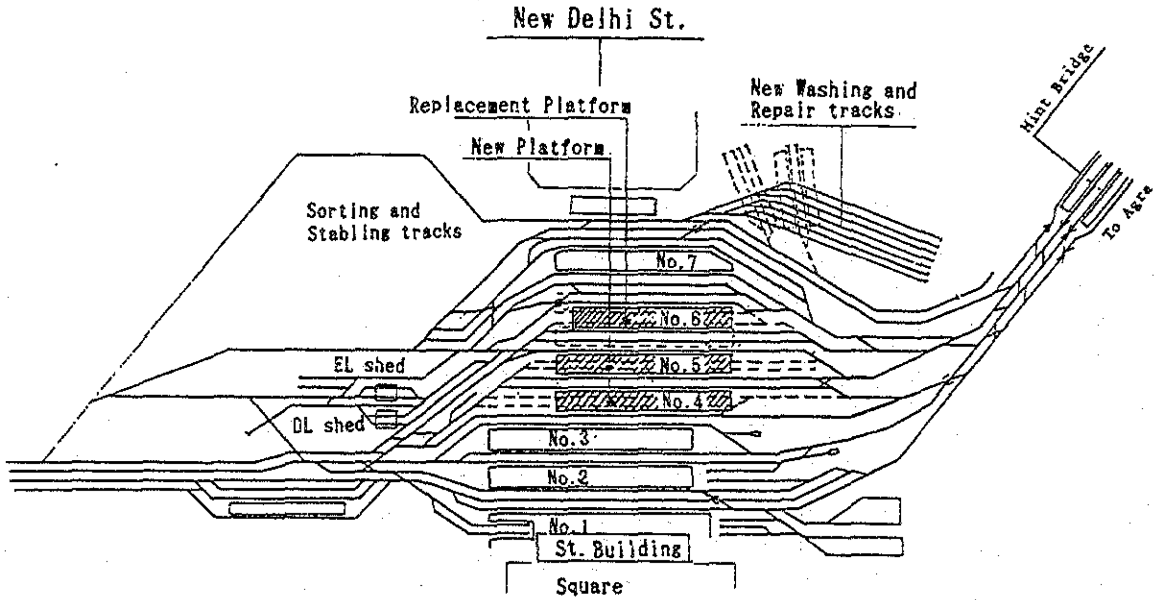
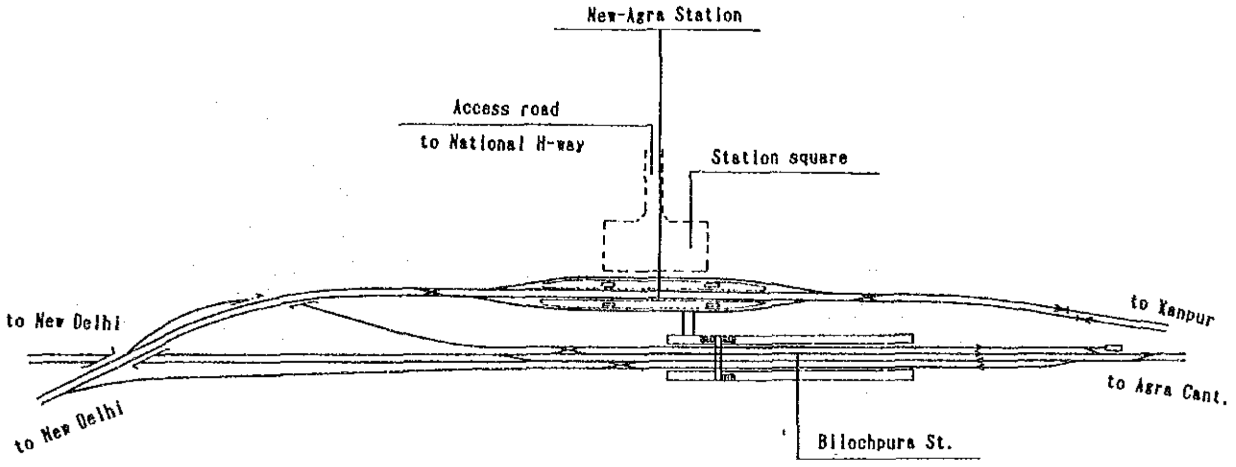


Fig. 5.5.1-3 Plan of the New Delhi Station



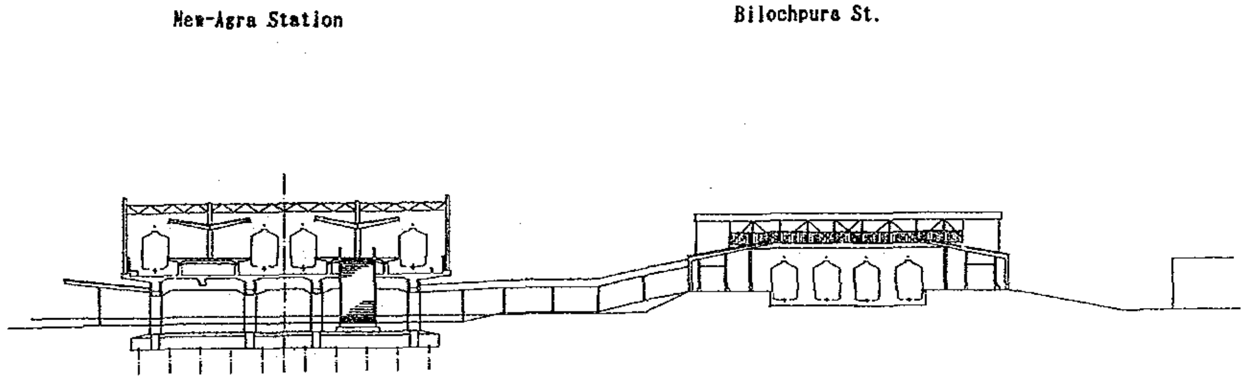
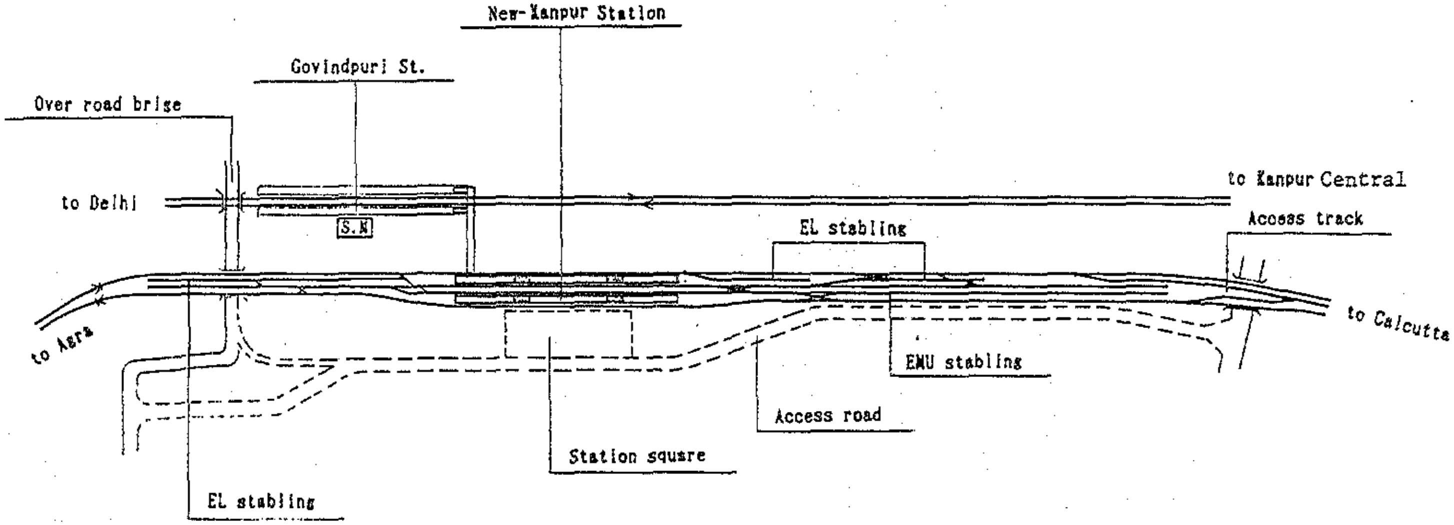


Fig. 5.5.1-4 Plan of the New-Agra Station



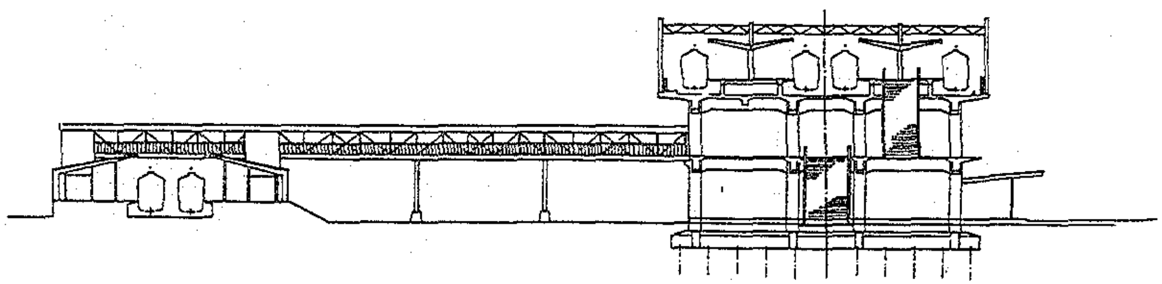


Fig. 5.5.1-5 Plan of the New-Kanpur Station

crossing with the Jansi Line and the over-road bridge before Govindpuri. The elevated station will have 2 platforms, 4 arrival/departure tracks, EMU stabling tracks, EL stabling tracks for exchanging locomotives, and EMU shuttling facilities. The station will have such track layout at the Calcutta side that allows the coming in and out of the Kanpur depot workshop and grade separated connection to the Calcutta Line. The Govindpuri Station will have transit installations to the conventional station. For EMU inspection and storage, 5 tracks will be prepared at the present SL shed area. The station plan is shown in the Fig. 5.5.1-5.

4) Intermediate station

Considering location of major cities, train operation diagram and the route length of 191 kilometer between New Delhi Station and New Agra Station, and 257 kilometer between New Agra and New Kanpur Station, 2 and 3 intermediate stations will be constructed for the former and the latter sections, respectively. The standard track layout of the intermediate station is shown in Fig. 5.5.1-6.

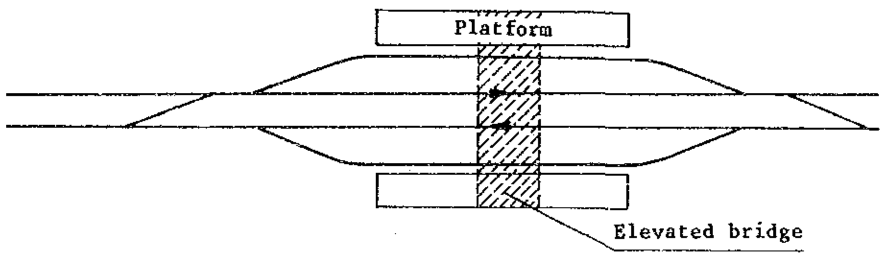


Fig. 5.5.1-6 Track Layout of the Intermediate Station

The crossover tracks will be laid on both side of the station for maintenance work and emergency purpose use. The station structure will be mainly embankment, while the central part of the station will be of the reinforced concrete bridge type with station office and equipment for passengers under it.

Fig. 5.5.1-7 shows the intermediate station plan near Mathura.

Fig. 5.5.1-8 shows location of the New Corridor Station.

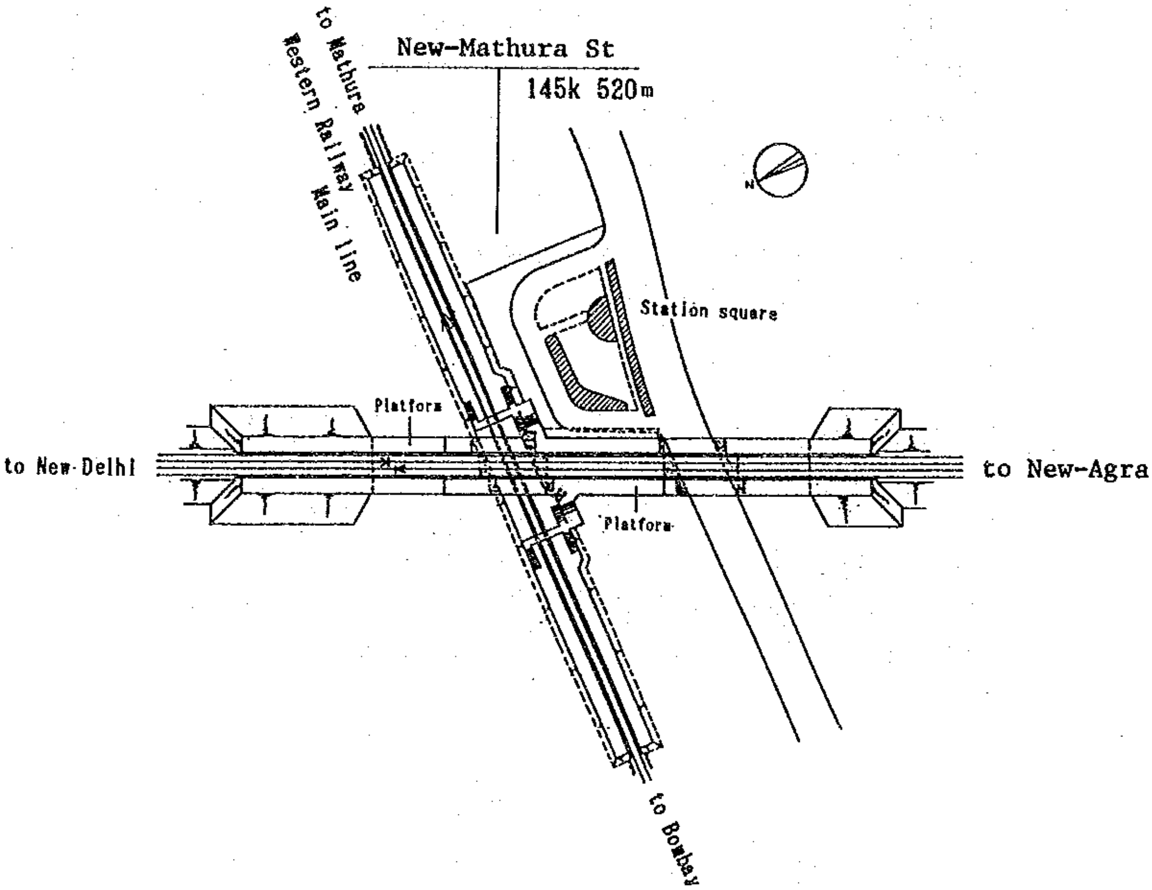


Fig. 5.5.1-7 Plan of Intermediate Station (New-Mathura)

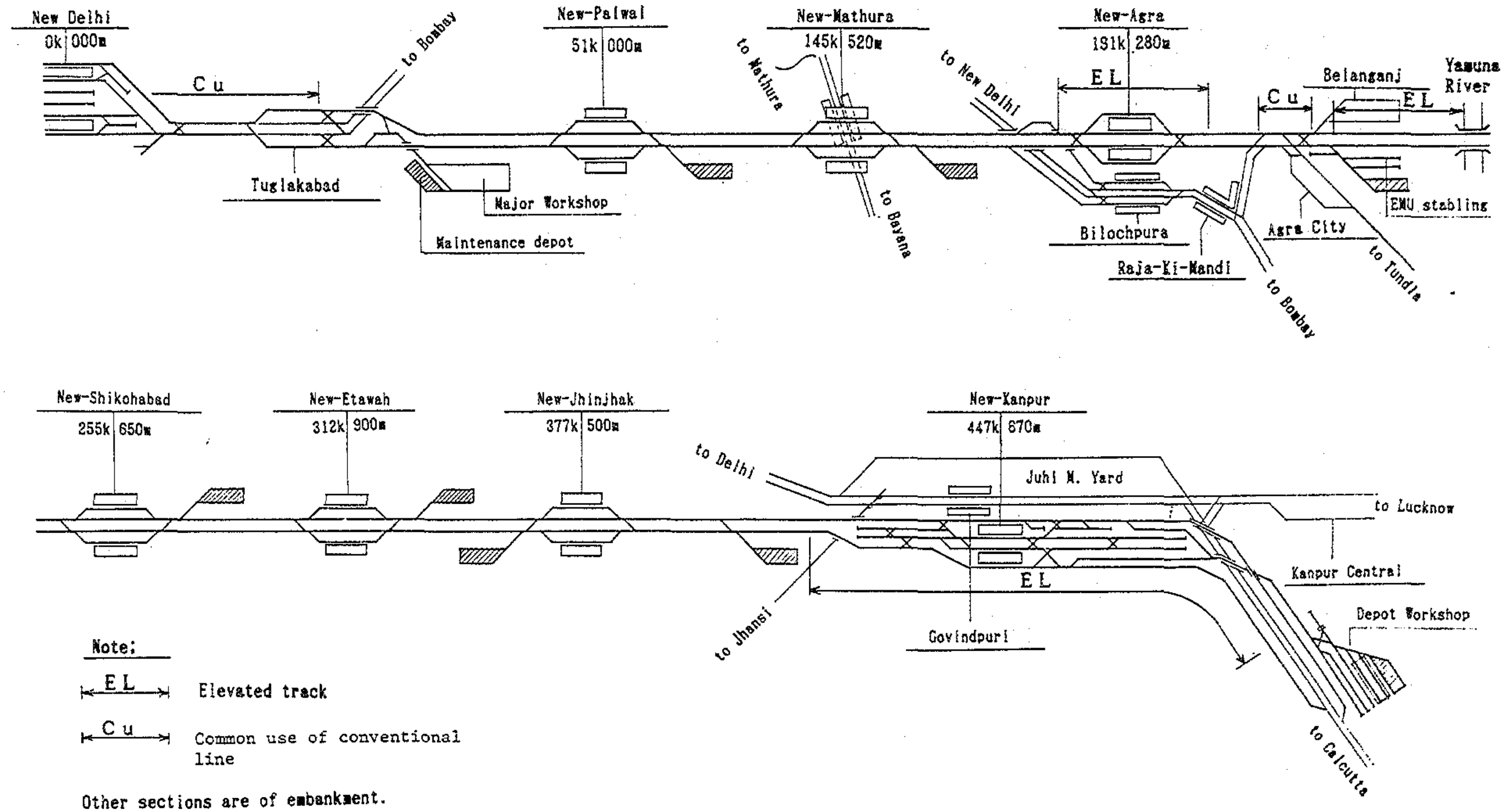


Fig. 5.5.1-8 Track Diagram of the New Corridor

(3) Rolling stock and maintenance facilities

1) Rolling stock workshop

For the New Corridor trains, a major workshop, depot workshop and stabling tracks will be newly constructed at Tuglakabad, Kanpur SL workshop and Agra, respectively.

The following facilities will be installed at a major workshop.

a) Track

. Access track . Arrival/Departure and Stabling track
. Draw-out track . Rearrangement track . Daily inspection track
. Intermediate inspection track . Bogie inspection track
. Periodical inspection track . Wheel grinding track
. Test running track . Material or storage track

b) Building

. Daily inspection shed . Inspection work building
. Wheel grinding shed . Warehouses . Office building, etc.

c) Equipment

. Electric power receiving and distribution equipment
. Water supply and drainage equipment . Boiler
. Car washing machine . Crane . Air compresser
. Wheel grinding machine . Machinery

Appendix 4-19 shows outline of proposed workshop for the New Corridor.

2) Maintenance depot (Track and OHE)

Maintenance depots will be constructed at about every 50 kilometers.

Their details are set forth in Chapter 6 IMPROVEMENT OF MAINTENANCE.

5-5-2 Signalling and Telecommunications

(1) Basic policy

1) The facilities corresponding to the national circumstances in India and the future projects of IR will be planned with reference to the facilities of the Japanese Shinkansen, because train speed, traffic volume and rolling stock performance of the New Corridor are similar to those of the Shinkansen.

2) The safety of train operation will be attached high importance taking into account the high train speed.

3) The minimum facilities required shall be installed at the time of inauguration of the New Corridor keeping economy in mind.

(2) Signalling facilities (Refer to Appendix 5-20)

1) ATC

a) In view of high train speed of 250 km/h, the Automatic Train Control (ATC) featuring high safety level will be used.

b) The jointless AF track circuit will be used for train detection and ATC data transmission. (On the premises of the insulation efficiency improvement of the PRC sleeper)

c) The signalling facilities will be concentrated to a signal cabin to attain higher reliability and simpler maintenance.

d) ATC will be adopted in the section of the conventional line where the New Corridor trains are jointly operated.

2) Interlocking device

Solid-state interlocking device will be used.

3) CTC

a) For smooth train operation, the centralized traffic control system (CTC) will be used.

b) The CTC centre will be located at Agra, the central point of the New Corridor.

c) The train route at each station will be controlled at the centre according to train location and train number data transmitted from each station through CTC.

d) The CTC center will provide traffic information required to each station

(3) Telecommunication facilities (Refer to Appendix 5-21)

1) Telecommunication system

The trunk transmission lines will be composed of the optical fiber and microwave links. The critical circuits used for the CTC/CSC and dispatch telephone will be of a dual transmission system using the above two transmission measures.

2) Train radio

The train radio system of 300 MHz will be used in consideration of the coordination with the trains commonly used for the conventional line.

3) Passenger service system

The passenger-information real-time signboards for train arrival/ departure, installed at platforms, concourses, etc. will be automatically controlled from the CTC center.

4) Maintenance radio

The portable wireless will be provided in order to facilitate maintenance work and failure recovery.

5-5-3 Electrification

(1) Preconditions

1) Route

Planning of the electrification system is made under the route shown in 5-2-2.

2) Traffic volume

The train traffic in 2000 is assumed that 60 Super Express EMU trains per day at max. 250 km/h and 50 L. express trains per day at max. 160 km/h, and in 2010, 90 and 70, respectively (in both directions) will be operated.

(2) Basic principle

1) In terms of the maximum train speed and traffic volume, the new corridor is considered to be on the same level as of the Shinkansen in Japan. Therefore, in planning the electric power supply, highly reliable equipment as of the Shinkansen level will be adopted.

2) The basic principles as for the consideration of economy, the use of Indian products, and the transfer of technology to upgrade the railway technology of IR are the same as that described in 4-4-3 (1) 1).

(3) Selection of the optimum feeding system

Among Simple, BT, and AT feeding systems, the AT feeding system is considered most suitable, for it enables to supply a large electric power with the least interference on telecommunication lines and the minimum construction cost.

(4) Power receiving points and the number of substations

The AT substation interval is expected to be about 80 km in view of the load conditions described in (1) 2). Taking this and the route of power transmission lines into account, the following 6 substations are provided. Table 5.5.3-1 and Fig. 5.5.3-1 show the power supply plan for the New Corridor.

Table 5.5.3-1 Power Supply Plan

RlySS No.	Kilo-post	Interval (km)	Power receiving substation	Supply Auth.	Receiving voltage	Remarks
1	40		Ballabgarh	NTPC	220	SS Nos.
		90				
2	130		Mathura	SEB	132	1, 2 & 3,
		70				
3	200		Agra	NTPC	220	Delhi-
		70				
4	270		Shikohabad	SEB	132	Agra S
		90				
5	360		Phaphuno	SEB	132	
		80				
6	440		Kanpur	SEB	132	

Note: The kiloposts of substations are assumed values.

(5) Substation(SS)

1) Power receiving voltage: 220 or 132 kV

2) Main circuit connection: Refer to Appendix 6-3

3) Transformer: Single phase 60 - 80 MVA, 2 banks

4) Circuit breaker: Equipped per each feeding circuit, with high-speed, automatic reclosing device

5) Protection: Main: Distance relay with the characteristic of parallelogram;
Back up: ΔI relay;
Fault locator: AT neutral current ratio type

(6) Sectioning post (SP)

SP is installed between SSs; CBs are installed at SP for feeding power extension; interrupters are installed at SP if required for parallel feeding of up and down lines: As for main circuit connection, refer to Appendix 6-3.

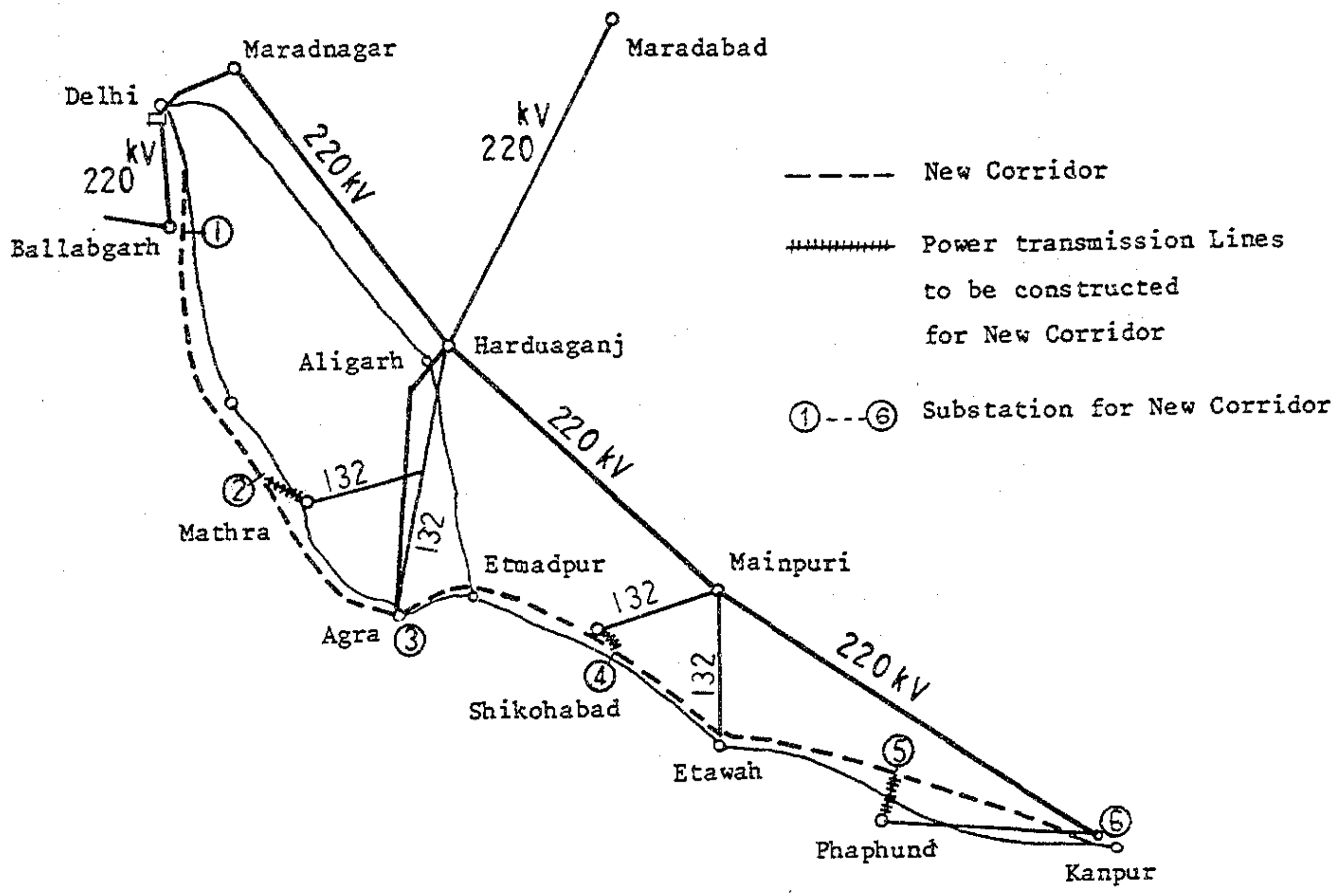


Fig. 5.5.3-1 Power Supplying Plan for the New Corridor

(7) Sub-sectioning post (SSP)

SSP is installed, as a rule, in between SS and SP; interrupters are installed at SSP for sectional feed suspension. As for main circuit connection, refer to Appendix 6-3.

(8) Autotransformer (AT)

Capacity: 5,000 kVA (selfcapacity);

Interval: 13 - 18 km

(9) OHE system

Taking into account the traffic volume or load conditions described in (1) 2) and the items shown in Fig. 4.4.3-2, the OHE system for the New Corridor is specified as shown in Table 5.5.3-2:

Table 5.5.3-2 Standard Features of OHE System for the New Corridor

Item	250 km/h
Type of OHE system	High tension compound catenary system with presag
AT feeder wire	ACSR 320 mm^2
Protective wire	ACSR 94 mm^2
Kind of catenary wire	St 148 mm^2
Kind of auxiliary catenary of switched wire	Cu 130 mm^2
Kind of contact wire	150 mm^2, hard drawn copper
Tension length	1500 m
Regulated or unregulated	Regulated
Max. span length	60 m
Stagger	$\pm$15 cm
Height of contact wire	5.2 m
Section on main line	Insulated overlaps
Current carrying capacity	920 Amps

Fig. 5.5.3-2 shows the standard structure diagram.

High tension compound catenary system, 250 km/h

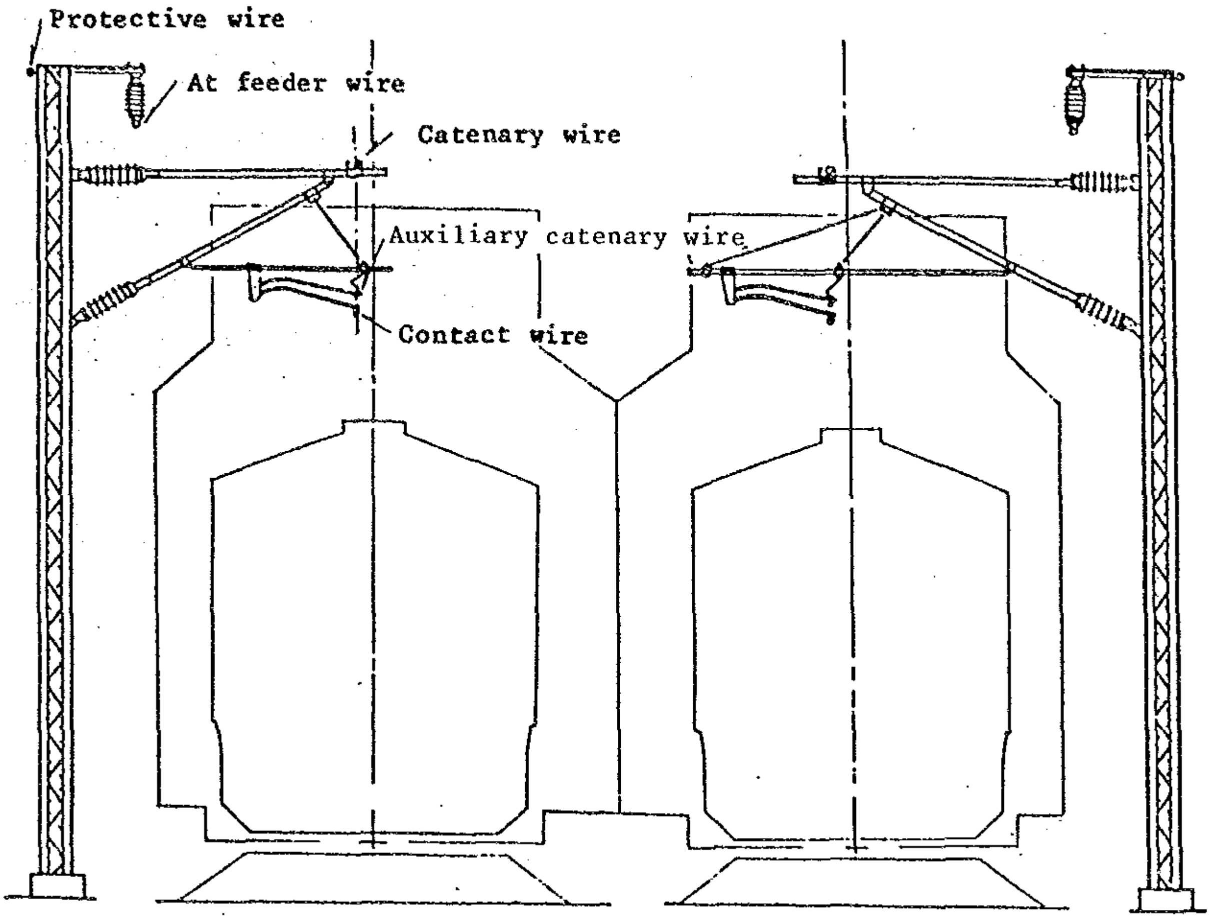


Fig. 5.5.3-2 The Standard Structure Diagram of AT Feeding OHE System

(10) Substation remote control system and control center (CC)

1) Remote control system

System equivalent in grade and capacity to the latest system of JR

- Time required for communication: 1.5 sec or less
- Transmission speed: Frequency modulation, 1,200 bit/s
- The number of points controlled per group: Max. 8
- The number of the control items per point: 16 - 84
- Controlling device: Microprocessor

Appendix 6-2 outlines the system.

2) Control Center (CC)

The location of CC is assumed at Agra for the following reasons:

a) Agra is situated mid between Delhi and Kanpur, and

b) Agra will be located at a center when the New Corridor is extended from Agra toward Bombay later on.

Selecting the CC location should be made putting importance on the factors, such as the train dispatching system and maintenance system of the New Corridor than the technical viewpoint.

5-6 Training

The New Corridor, being employing many new technologies, will require sufficient tests, education, and training. At the Tokaido Shinkansen, which started high-speed commercial operation at 210 km/h for the first time in the world, an approximately 20 km railway line was completed earlier than the rest of the line. This model section was used for the actual running tests for 2 years before commercial operation started so that all possible problems could be identified and unknown factors could be solved. During that period, examination on the performance of rolling stock, various machines, equipment, and facilities, establishment of maintenance standards, and on-the-job training were executed. Such activities enabled a smooth start of commercial operation.

In case of the New Corridor construction, in addition to fundamental education and training at the training school, a model section should be utilized to execute the following tests and training by actually operating vehicles.

- Performance check of high-speed rolling stock
- Performance check of ATC equipment, substation facilities, etc.
- Establishment of track maintenance standards
- Performance check of OHE
- Development of inspection techniques for tracks and electric facilities designed for 250 km/h high-speed operation
- Training of crew for operation and handling of on-board equipment
- Development of handling and maintenance procedures for various ground facilities

A high level of maintenance techniques are required to maintain the 250 km/h EMU.

For such a purpose, maintenance crew should be trained at schools and factories as outlined below.

- Daily inspection, intermediate inspection:
  Acquisition of inspection items and inspection methods
- Bogie inspection:
  Training on the new machines installed for inspection of high-speed bogies.

- Periodical inspection:
  Training for handling the new types of machines and facilities, using a simulation vehicle.

5-7 Rough Investment Plan

5-7-1 Investment Timing

The start of operation is scheduled for the year 2000, with the time for construction set as the 5 year period between 1995 and 1999 (Table 5.7.3-5).

5-7-2 Premises

In addition to the premises described in 4-6-2, the following are assumed.

(1) Estimating of expenses necessary for the imported materials/facilities will be made referring to the recent Shinkansen project.

(2) Investment for rolling stock will be estimated with the assumption that 5 sets of Super Exp. train will be imported by 2000 and other rolling stock will be manufactured domestically.

5-7-3 Investment Cost and Implementation Schedule

(1) Investment Cost

1) Initial investment

a) Ground facilities

Table 5.7.3-1 The New Corridor Construction Cost

(10^6Rs)

Item	Local currency	Foreign currency	Total
Land acquisition	537.2	0	537.2
Track and structure	9,469.7	0	9,469.7
Signalling and telecommunication	1,447.5	1,310.8	2,758.3
Electrification	1,816.5	199.0	2,015.5
Total	13,270.9	1,509.8	14,780.7

b) Rolling stock

Table 5.7.3-2 The New Corridor Rolling Stock Cost

(10^6Rs)

Fare increase (%)		0	25	50	75	100
Cost	Local currency	4,470.6	3,182.1	2,106.3	1,280.7	905.4
	Foreign currency	1,251.0	1,251.0	1,251.0	1,251.0	1,251.0
	Total	5,721.6	4,433.1	3,357.3	2,531.7	2,156.4

2) Additional Investment (Local currency)

a) Ground facilities

None

b) Rolling stock

5.7.3-3 Rolling Stock Additional Investment Cost

(10^6Rs)

Fare increase (%)	0	25	50	75	100
2000 ∿ 2004	1,760.5	1,848.1	1,685.5	1,435.3	1,310.2
2005 ∿ 2009	970.3	2,058.7	1,869.9	1,707.3	1,457.1
2010 ∿ 2014	0	0	1,050.9	888.3	638.1
2015 ∿ 2024	0	0	125.1	1,739.1	1,526.4
Total	2,730.8	3,906.8	4,731.4	5,770.0	4,931.8

3) Detailed initial investment cost

Table 5.7.3-4 Detailed Initial Investment Cost for Construction of the New Corridor

(10^6Rs)

Item			Total	Breakdown: Personnel expenses in local currency	Breakdown: Other expenses in local currency	Breakdown: Foreign currency
Land	Price of land for tracks laying		486.8		486.8	
	Price of land for stations and station plaza		20.4		20.4	
	Other land prices		30.0		30.0	
Track and structure	Roadbed		4,076.7	611.5	3,465.2	
	Over-road bridge, elevated bridge		1,408.3	281.7	1,126.6	
	Platform		87.1	17.4	69.7	
	Footbridge		50.2	10.0	40.2	
	Station building		72.7	14.5	58.2	
	Rolling stock shed		81.6	16.3	65.3	
	Tracks		3,101.6	496.3	2,605.3	
Signalling/tele-communication	Level crossing facilities		0			
	Signalling equipment		720.8	154.3	122.5	444.0
	Telecommunication equipment		1,178.3	468.0	166.0	544.3
	Signalling cable		163.9	57.5	101.0	5.4
	Telecommunication cable		510.9	250.6	61.4	198.9
	Track circuit		184.4	26.0	40.2	118.2
Electrification	Substation equipment		658.9	83.5	376.4	199.0
	Substation building		35.8	7.2	28.6	
	Overhead equipment		1,298.8	356.4	942.4	
	Power distribution		22.0	5.0	17.0	
Rolling stock plant machinery facilities			591.5		591.5	
Ground facilities - subtotal			14,780.7	2856.2	10,414.7	1,509.8
Rolling stock	Fare increase (%)	0	5,721.6		4,470.6	1,251.0
		25	4,433.1		3,182.1	1,251.0
		50	3,357.3		2,106.3	1,251.0
		75	2,531.7		1,280.7	1,251.0
		100	2,156.4		905.4	1,251.0

(2) Implementation Schedule

Table 5.7.3-5 Implementation Schedule (Construction of the New Corridor)

(10^6Rs)

			Fiscal year	1994	1995	1996	1997	1998	1999
Pre-feasibility study				— 1987					
Securing budget				—					
Ground facilities	Designing				—	—	—		
	Manufacturing				—	—	—	—	
	Con-struc-tion	Track/ structure			—	—	—	—	—
		Signalling/ telecommuni-cation				—	—	—	—
		Electrifi-cation				—	—	—	—
Rolling stock	Designing				—	—			
	Manufacturing						—	—	—
Test, training									—
Preparation for inanguration								—	—
Ground facilities	Local currency				1,695.6	3,299.5	3,727.5	3,699.4	848.9
	Foreign currency					393.2	472.8	472.8	170.9
	Total				1,695.6	3,692.7	4,200.3	4,172.2	1,019.8
Rolling stock	Local currency		0%					2,196.5	2,274.1
			25%				34.1	1,543.7	1,604.3
			50%				102.2	988.8	1,015.3
			75%				170.4	558.9	551.4
			100%				170.4	371.3	363.7
	Foreign currency						625.5	625.5	

CHAPTER 6 IMPROVEMENT OF MAINTENANCE

CHAPTER 6 IMPROVEMENT OF MAINTENANCE

6-1 Rolling Stock

6-1-1 Rolling stock on the Section

Maintenance in the shed plays major role of rolling stock in IR. (The EL maintenance cost in the shed accounts for about 88% of the total EL maintenance cost in the N.R).

In this regard, implementation of the following measures are recommended to enable handling the increased number of ELs in future (1.5 times more than the current number) without necessitating additional sheds and a large number of maintenance personnel.

- Suppressing the maintenance for rolling stocks by extending the inspection cycle.
- Enhancing the inspection capacity of the shed by reducing the days required for inspection.
- Reducing the number of non-scheduled inspections by reducing rolling stock failures.
- Introducing inspection equipment for the high-speed EL (160 km/h).

Examples in JR which may help in promoting the above measures are described below.

As for coaches and wagons, while the basic concept is the same as for ELs, it is desired to improve the current inspection facilities because it seems inferior to that for ELs.

(1) Maintenance Control

1) Category of failure

Failure of the rolling stock is generally categorized into initial failure, accidental failure, and wear failure.

- Initial failure: Occurs mostly due to defective quality control in the manufacturing process.
- Accidental failure: Apt to occur due to overstress and overload more severe than assumed design conditions.

- Wear failure: Occurs due to wear, decay, and fatigue corrosion etc. proportional with the period of use.

Initial failures and accidental failures can be decreased by improvement of the manufacturing and quality control system.

Most wear failures can be eliminated by ensuring quality control made in consideration of use period.

2) Maintenance system

Inspection/repair methods of rolling stock are classified into the following three methods.

a) Preventive maintenance

The greater the degree of failure/deterioration of equipment instruments, the greater is the cost for restoration along with greater danger in terms of safety. Therefore, periodical maintenance and repair should be carried out when the failure or defect is within a certain limit to ensure safety and prolong the service life of rolling stocks.

Especially, a failure due to electric deterioration may result in greater damage requiring a greater repair cost. Therefore, it is necessary to carefully examine the character of electrical deterioration and the remaining service life and carry out preventive maintenance in an appropriate cycle.

b) Upgrading maintenance

For rolling stock with a longer service life such as those of electric locomotives, it is desirable to carry out upgrading maintenance for further improvement of the performance by introducing the latest technology during the period of use.

c) After-the-event maintenance

Parts and equipment which are not directly tied to the safety and performance of rolling stocks may be subject to after-the-event maintenance, provided it does not affect the train operation and is economical.

(2) Cycle and content of inspection

1) Cycle of inspection

The regular inspections of JR consist of three kinds of inspection: periodical, intermediate, and dialy.

Daily inspections are performed every day, while when a certain period or operation kilometers are reached, intermediate or periodical inspections are carried out.

Appendix 3-18 shows the inspection cycle for coaches and electric locomotives of IR.

Appendix 3-19 shows the cycle and content of inspection for coaches and electric locomotives of JR.

Although the cycle of inspection at coach sheds is almost identical in the cases of IR and JR, cycles of monthly inspection and annual over-haul (AOH) inspection with regard to EL are not, with cycles of IR being about one third and two thirds of those of JR, respectively.

As for inspection items, little difference is seen between IR and JR.

2) Determination of inspection cycle

Some parts of rolling stocks are subject to wear and deterioration due to operation and others to deterioration merely due to aging. In addition, the character and degree of deterioration is largely affected by track conditions, environmental circumstances, running distance, and operation frequency/speed.

Because rolling stocks have a longer service life and their function and structure are bound by the technical level at the time of manufacturing, the degree of deterioration may differ depending on the time of production and years passed even for the same type of rolling stock.

The cycle of periodic inspection, therefore, should be appropriately determined in consideration of these conditions. To this end, it is necessary to examine and record, the degree of deterioration and wear at every periodical inspection.

The cycle of inspection is closed when either the running kilometers or the length of time reaches a predetermined value.

3) Extending the cycle of inspection

Attempting a longer cycle of inspection, it is necessary to accurately examine what may form the limit for extending the current inspection cycle from the repair records. In accordance with the study result, the problem must be solved by improving the repair method, designing and quality control method.

It is also desirable to extend the inspection cycle and service life by introducing advanced technology into any area of design, inspection, or repair for rolling stocks and equipment.

For instance,

a) Use a paint-free material such as aluminum or stainless steel for the exterior of a body.
b) Use semiconductors to make non-contact circuits.
c) Adopt higher insulation rank.
d) Use as much resin as possible for mechanical parts to minimize the number of sliding parts, thus making them free from lubrication.

(3) Reducing the number of days for inspection and repair

The repair capability of a shed by the same equipment can be expanded by cutting down the days for inspection and repair.

An example of the flow of inspection and repair is shown in Fig. 6.1.1-1 below.

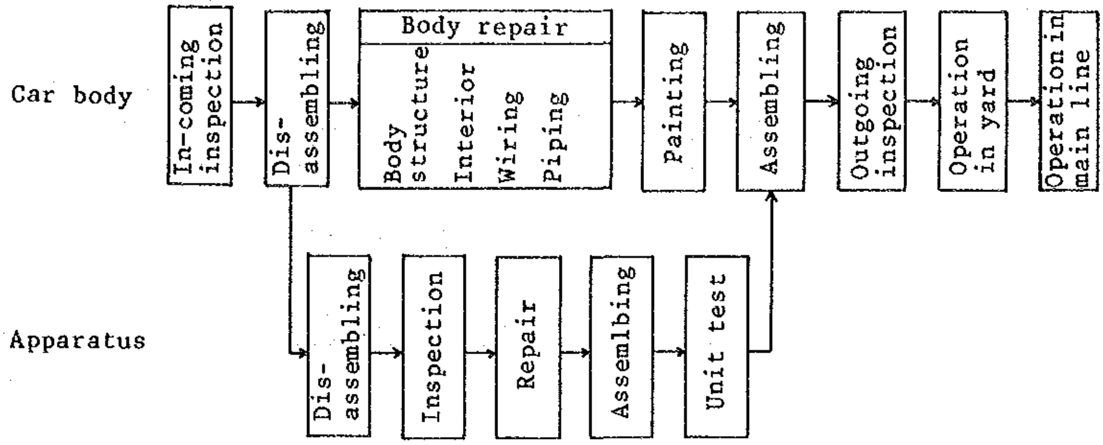


Fig. 6.1.1-1 Flow of Work

The whole process may be greatly affected by the following problems. So every effort should be made to find their solution.

1) Corrosion, deterioration and damage of body structure of steel, wiring, and piping.
2) Capability in each unit work.
3) Equipment for disassembling, assembling, and painting.
4) Purchase of parts, equipment, and materials.
5) Inspection and repair schedule of equipment.

For instance, it helps to reduce the repair period to eliminate the painting process by using aluminum and stainless steel, to work on wiring, apparatus mounting, and parts painting in parallel processes, as well as to examine record of the rolling stock before preparing repair schedule.
It is also desirable to automate and rationalize as much as possible such routine works as disassembling, assembling, carrying, cleaning, etc.

Since apparatus is removed from the body to undergo inspection and repair in other processes, if this process takes more days than the body process, spare parts may be utilized to equalize the both process time.

It is also important to carefully prepare stock parts based on reasonable inventory control in consideration of the parts usage record.

(4) Quality control

It is necessary to regularly check if the repair work is carried out as scheduled and conforms to the standard in the following manner.

1) Establish the working standard and make it familiar to all workers.

2) Properly control the process, working method, materials, machines and instrument tools for each type of work.

3) Give workers a thorough education and training for the purpose, necessity, and method of quality control.

4) Establish an responsibility system under which a manager and each worker shall take charge of the work within their duty. A quality control system is also required with workers' mutual checks.

5) Investigate the cause of a defect, hammer out a comprehensive remedy, and feed it back to the design aspect and maintenance method.

6) Encourage workers to freely make proposals concerning improvement of working system, design, work tools/apparatus, etc.

(5) Countermeasures to defects

When a failure occurs, make detailed investigation on the circumstances of the occurrence and discover its cause to come up with an appropriate countermeasure.

If the cause is uncertain, it is desirable to carry out various simulated failure tests including the following items: material, shape (reinforcing conditions etc.), extent of crack, repetition frequency, temperature, humidity, stress (or torque), amplitude, acceleration of vibration, fixing system.

Especially for frequent failures, the effects of countermeasures should periodically be followed up.

(6) Maintenance equipment

Appendix 3-20 shows an example of equipment for automating the routing works such as disassemling, assembling, carrying, etc.

Appendix 3-21 shows an example of the inspection equipment for electric locomotives and coaches for high speed operation.

6-1-2 The New Corridor

The inspection and repair equipment for high-speed rolling stock will be more efficient and sophisticated than those for existing railways, thus making their maintenance system rather different compared with the conventional one.

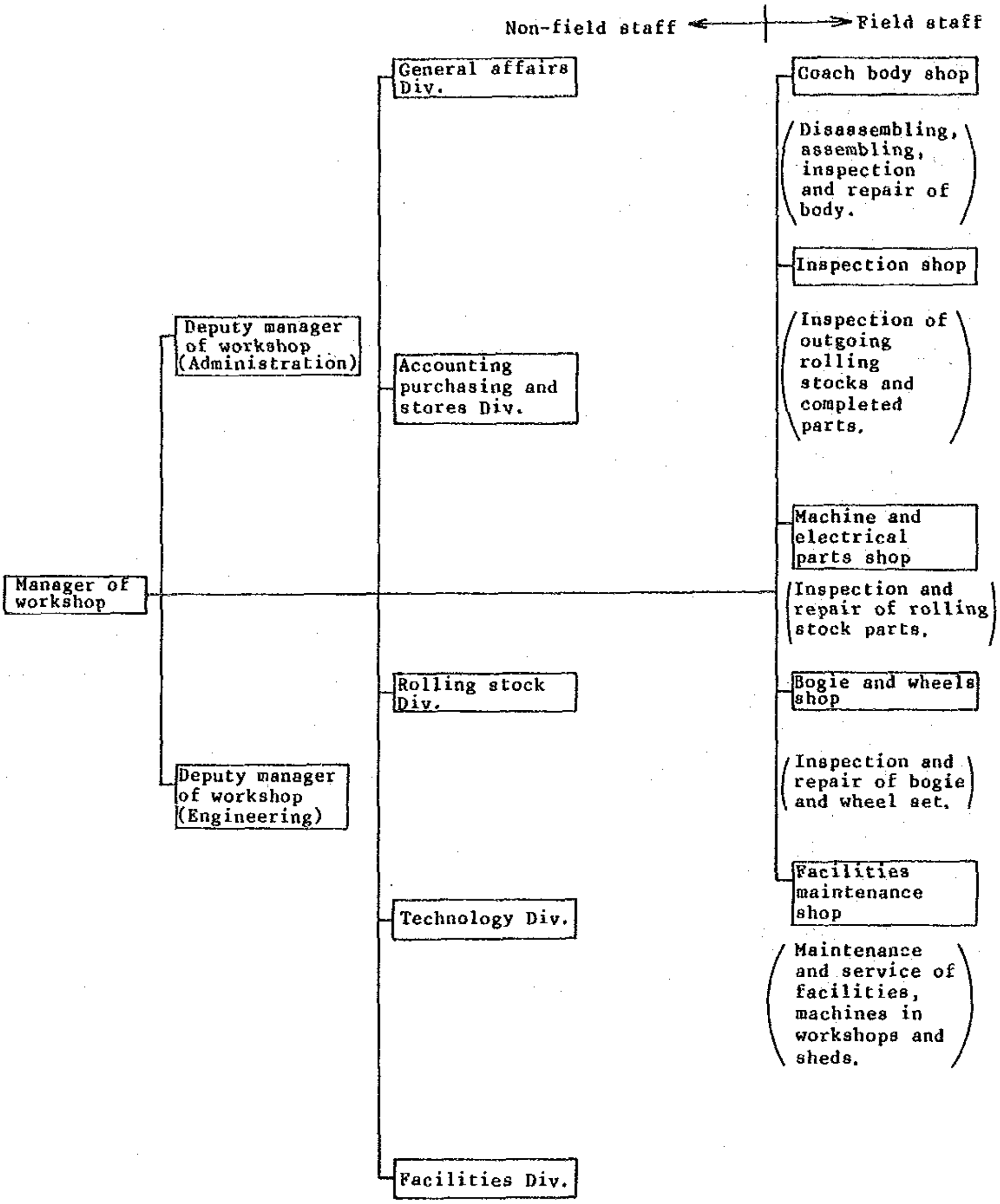
Described below is an example of the organization, personnel, machines, and equipment of a Shinkansen repair workshop in Japan.

(1) Maintenance system

1) Organization

Organization of the field staff and non-field staff is shown in Table 6.1.2-1.

Table 6.1.2-1 Organization Chart of a Workshop



2) Personnel

Assuming that the number of rolling stock to be handled is 700, the number of annual repairs is 280 in periodical inspections and 650 in bogie inspections, the allocation of personnel for both field and non-field is shown in Table 6.1.2-2.

The number of rolling stock to be handled by IR in the year of 2000 will be about 400, while the staff will be made up of about 450 people.

Table 6.1.2-2 Personnel Allocation

	Duty	No. of people		Duty	No. of people
Non-field	Workshop manager	1	Field	Coach body shop	221
	Deputy manager	2		Inspection shop	33
	General Affairs Div.	15		Machine and electrical parts shop	147
	Accounting, Purchasing and Stores Div.	15		Bogie and wheels shop	118
	Rolling Stock Div.	12		Facilities maintenance shop	53
	Technology Div.	12			
	Facilities Div.	9		Sub-total	572
	Sub-total	66		Total	638

3) Inspection of rolling stocks

a) Types of inspection

Inspection is divided into daily inspection, intermediate inspection, bogie inspection, and periodical inspection as in existing railways. The outline of inspection system is shown in Table 6.1.2-3.

Table 6.1.2-3 Outline of Inspections

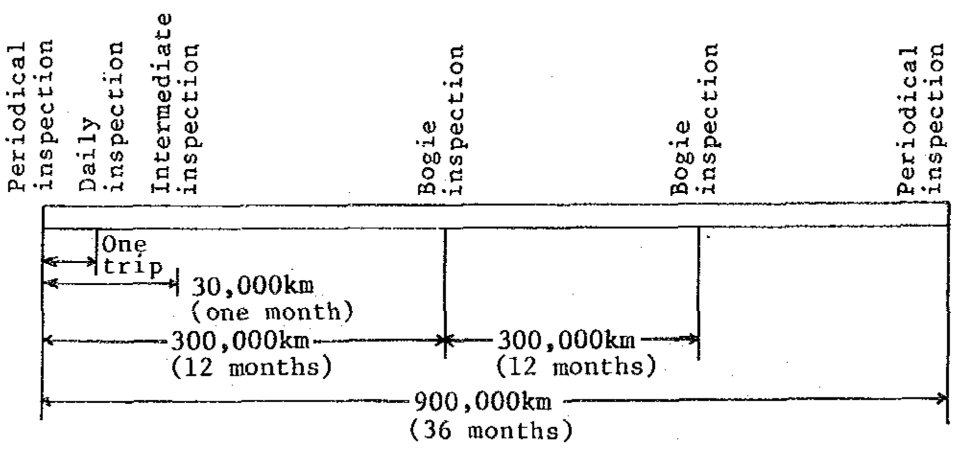
● : Those maintained at workshops

○ : Those maintained at sheds

Type	Description	Remarks
Periodical inspection	General inspection by disassembling parts at a certain cycle	●
Bogie inspection	Inspection performed for major parts such as traction motor, transmission, running devices and brake devices at a certain cycle	● ○
Intermediate inspection	Inspection performed for the condition and operation of important parts at a certain cycle	○
Daily inspection	Inspection performed from outside before operation for condition and operation of major parts	○
Non-scheduled inspection	Non-scheduled inspection performed as required in the event of accident or the like	● ○

b) Inspection cycle

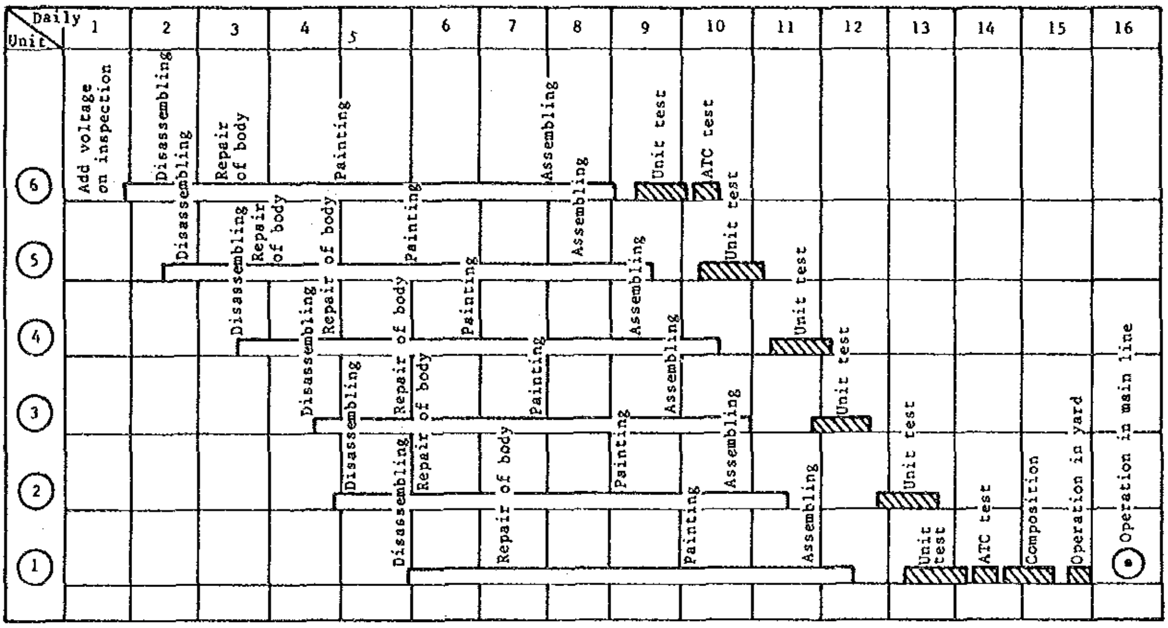
The inspection cycle is as shown below.



c) Inspection process

The periodical inspection process is shown in Table 6.1.2-4. Two vehicles form one unit which is shifted from station to station for inspecting.

Table 6.1.2-4 Periodical Inspection Process



d) Flow of inspection

Flow of inspection is shown in Fig. 6.1.2-1.

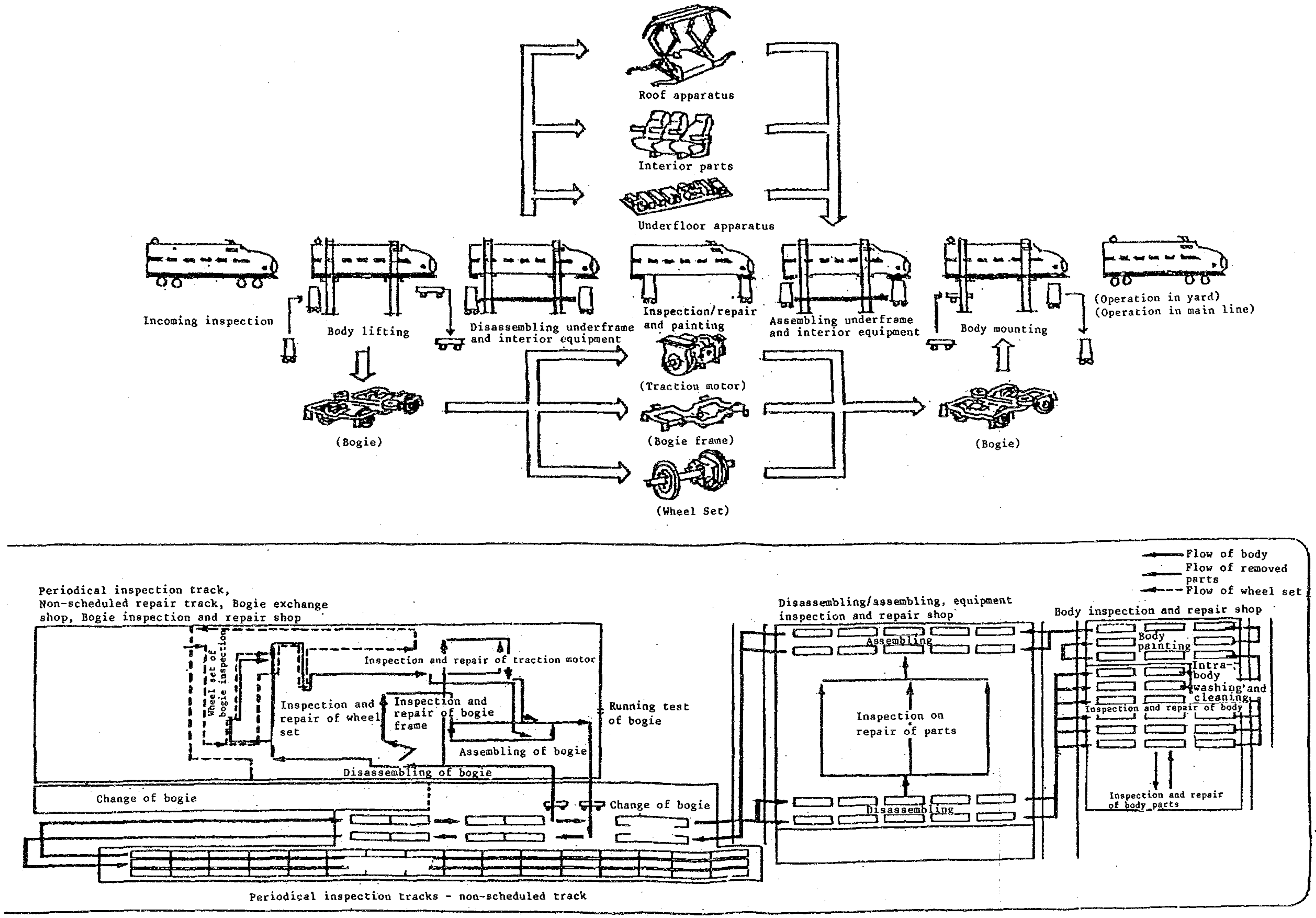


Fig. 6.1.2-1 Flow of Rolling Stock Inspection

(2) Facilities and machines

The maintenance works for Shinkansen rolling stock including daily inspection, intermediate inspection, bogie inspection, and periodical inspection, are collectively conducted at one place thus attaining high work efficiency and mobility. Fig. 6.1.2-2 shows an overview of its facilities and machines whose features are as follows:

1) They allow maintenance works on a unit (2 coaches) basis.

2) They are automated to a maximum allowing a conveyer system.

3) Control of facilities, examination and record of inspection, storing and carrying of parts are automated by using processing computers and numerical control devices.

Appendix 3-26 shows an example of the layout of inspection and repair facilities of Shinkansen.

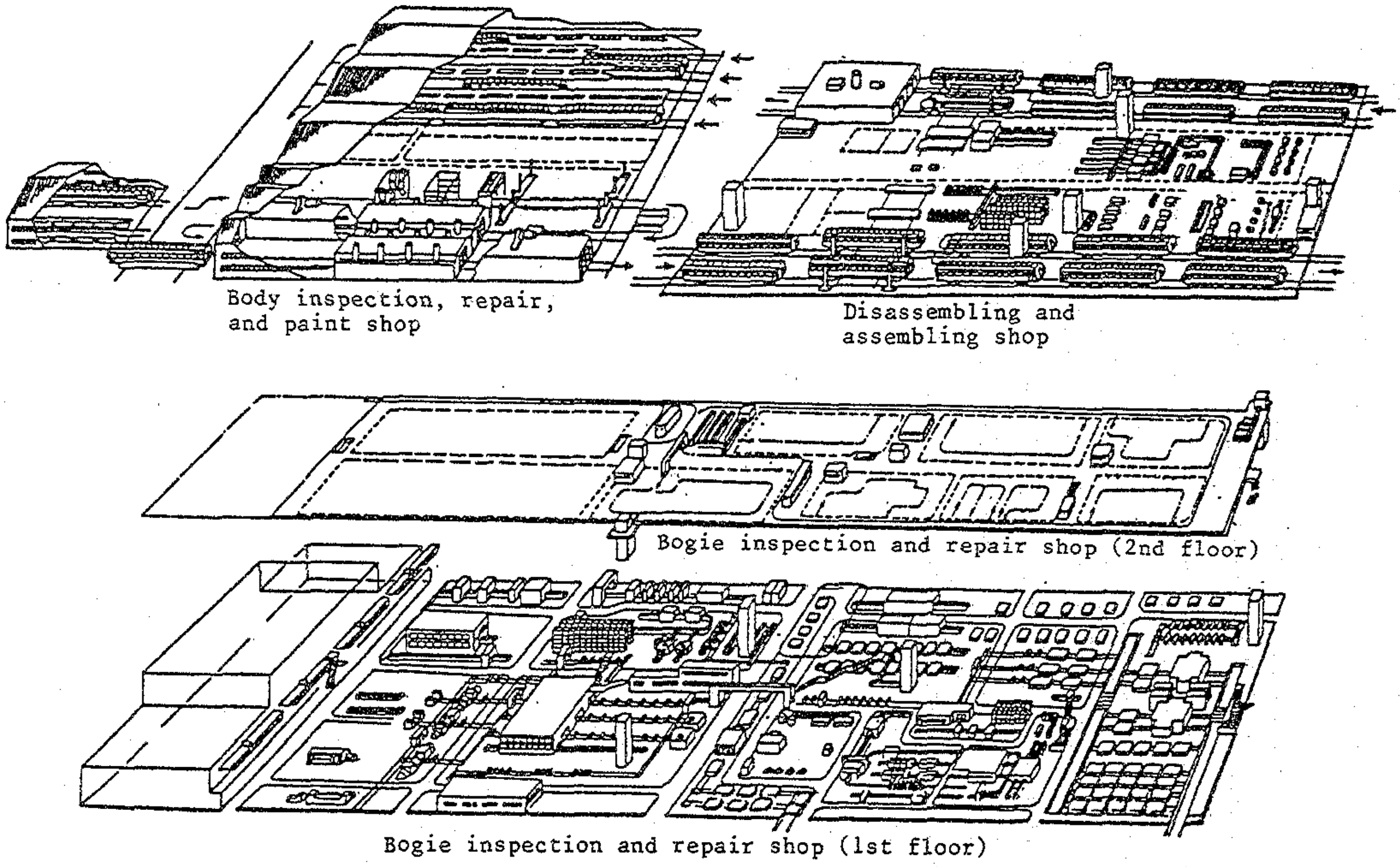


Fig. 6.1.2-2 Overview of the Facilities and Machine of Shinkansen Workshop

6-2 Ground Facilities of the Section

6-2-1 Track Management

(1) Track maintenance standards

1) Current maintenance standards

The current Indian Railways' maintenance standards Grade 'A' is as follows.

Unevenness: 0 to 6 mm on 3.6 m
Gauge : ±3 mm
Twist : 0 to 5 mm on 3.6 m at 1.39 mm/m
Alignment : up to 3 mm on 7.2 m

10 points exceeding the limit of an irregularity under each category is allowed in each kilometer length of track. If there are more than 10 points in one kilometer, the grade of the line should be changed to a lower grade.

The maintenance standards for existing lines and the Shinkansen in Japan are shown in the Appendix 4-20.

2) Future maintenance standards

For the future speed-up and increased maintenance work, it is advisable that Indian Railways should improve the following points.

a) Measurement chord

According to the measurement chord in the track inspection, 3.6 m is taken for unevenness, and 7.2 m for alignment. The 3.6 m for unevenness, in particular, is extremely short. Therefore, it is difficult to perform inspection of the wavelength of track irregularity which is most closely related with shaking of vehicles. Since the characteristic vibration of train is usually about 1 c/s, a 30 m and 40 m track irregularity wavelength affects most seriously the shaking of vehicles at a train speed of 120 km/h and 160 km/h, respectively. Apart from safety in train operation, therefore, it is important from the viewpoint of shaking of vehicles to check the track irregularity of a long wavelength and adjust it.

In Japan, a 10 m chord has been used for inspecting the track. The detection characteristic is shown in Fig. 6.2.1-1. According to this, the detection magnitude of 30 m and 40 m length track irregularity is 0.5 and 0.2 respectively, which cannot be used at a high-speed range. For the Shinkansen, therefore, measurement data by 10 m chord is processed for detection of 20 m chord by calculating.

Fig. 6.2.1-2 shows the inspection data of alignment irregularity with varied measurement chord and transversal direction at 200 km/h of the Shinkansen. The alignment irregularity by 10 m chord gives no information on transversal direction, but data considerably correlated with transversal direction are given by a 30 m or 40 m chord data. From the above fact, an inspection method which is good enough to detect an approximately 20 m wavelength is necessary in terms of the shaking of vehicles at a 160 km/h train speed.

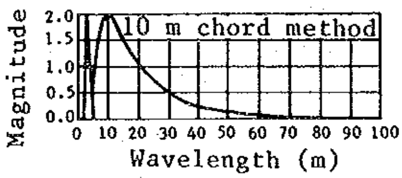


Fig. 6.2.1-1 Detection Characteristic by 10 m Chord

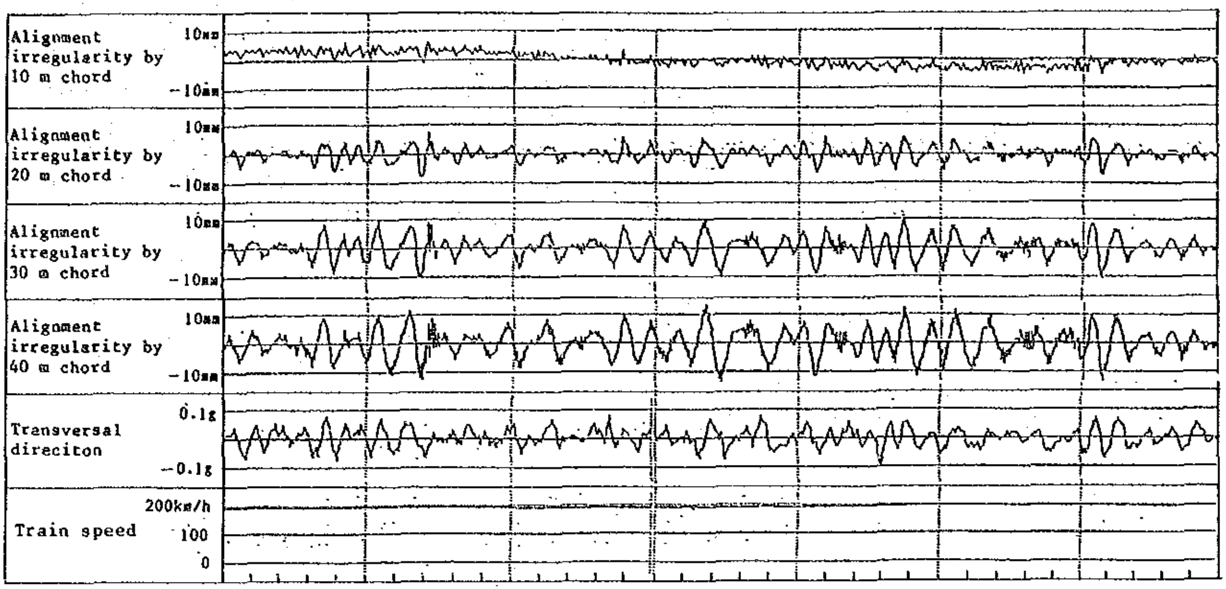


Fig. 6.2.1-2 Measurement Chord and Alignment Irregularity

b) Dynamic value and static value of track irregularity

Indian Railways uses Amslar cars in principle for inspecting track irregularities at a speed of 70 - 80 km/h. No clear discrimination is made between standards of dynamic and static values measured. According to measurement data taken in Japan, a certain relation can be observed between dynamic and static values as shown in Fig. 6.2.1-3. Based on this, standards are prepared.

Thus, dynamic measurement and static measurement are clearly discriminated. In view of the future speed inccrease, the chance for measurement after completion of track adjustment or emergency adjustment will increase. Consequently considering the limited number of using the inspection car, present dynamic measurement will not be sufficient. It is proposed, therefore, that static measurement standards must be prepared and used separately.

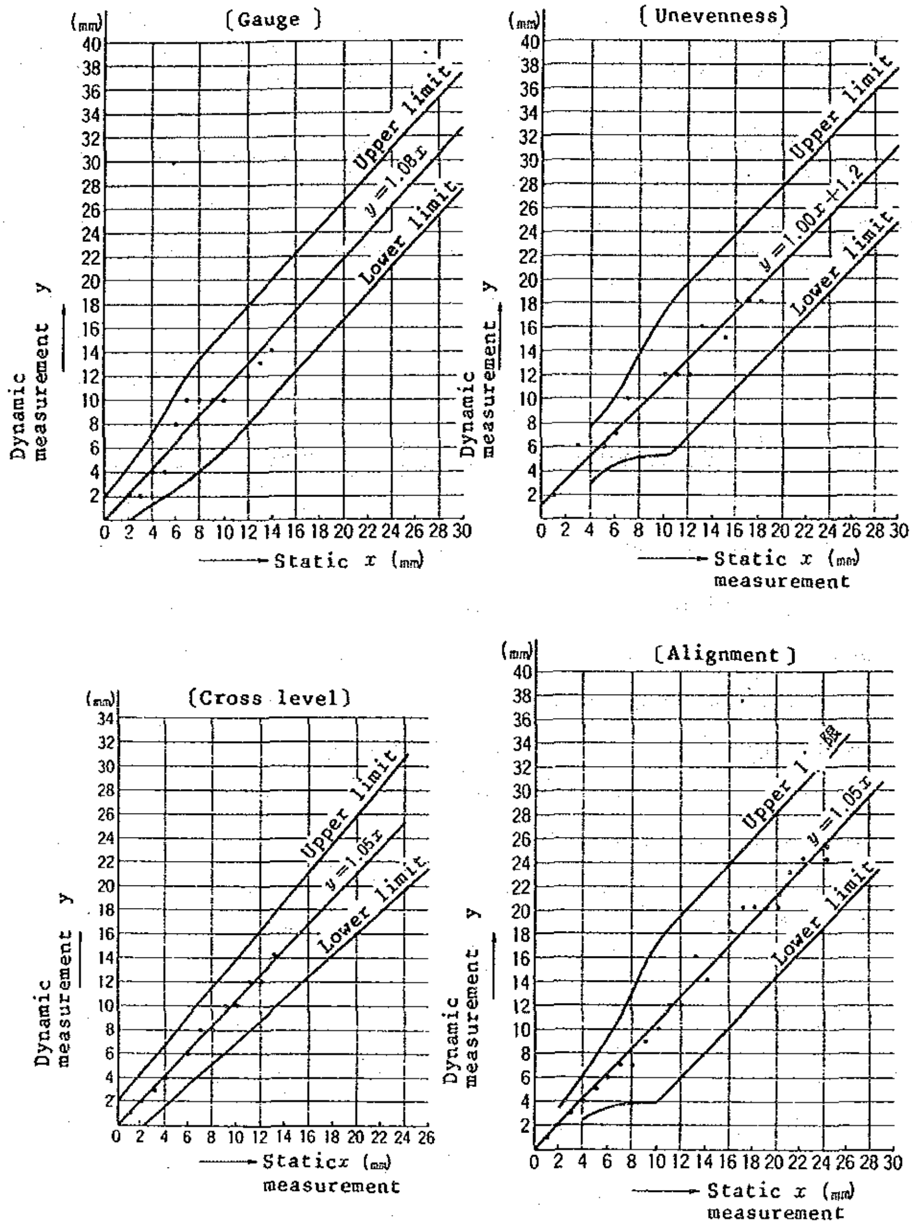


Fig. 6.2.1-3 Relation between Dynamic Measurement and Static Measurement

c) Maintenance standards by purpose

For the future speed increase and increased number of trains, systematic maintenance work using mechanical power is required. In this regard, preparation of maintenance standards in 3 categories is recommended as follows.

i) Finishing target values to be achieved after track upgrading, new construction, or track adjustment.

ii) Maintenance target values to be used for planning maintenance.

iii) Security control target values to be urgently prepared from the viewpoint of safety.

3) Setup of maintenance standard values

It is proposed that maintenance standard values in 3 categories should be prepared in the following manner.

a) Target value for maintenance planning

The method to prepare target values for maintenance planning is shown in the Appendix 4-20. The method actually used for the Shinkansen, which appears simple and practical, is recommended. In this method, plotting is made at 160 km/h on the relation between the vertical acceleration vibration and the unevenness, and the relation between the transversal acceleration vibration and the alignment. As the next step, the upper limit of acceleration vibration is determined from the corelation between the ride index and the acceleration vibration. Using the corelation between this vibration value and the said track irregularities, the standard values for unevenness and alignment are obtained. A little tighter values than these shall be set up as the target values for maintenance planning.

As to the gauge and twist, if the alignment and unevenness are maintained below the riding comfort target value, there is no relation observable between the shaking of vehicles and them. And the current standard values under Grade 'A' of Indian

Railways are good enough compared with those of the Shinkansen. Under the circumstances, the current standard values of Grade 'A' are considered applicable as they are.

b) Finishing target value

The standard value to be achieved after completion of a maintenance or construction works should be determined to satisfy the following conditions.

- The value should be within the range of a work capability.
- There should be a considerable time left before progress of an irregularity after adjustment reaches the maintenance standard value.
- The value should allow efficient adjustment work.

Tighter finishing value may extend the maintenance cycle, but requires a tremendous amount of time and work instead. About 3 mm is regarded as the limit of the finishing capacity in raising and overall tamping using machines. Inversely, too loose a finishing value will result in a shortened maintenance cycle, although the adjustment work is easy. Considering all these factors, an adequate value should be selected so efficient adjustment work can be performed.

c) Target value for safety control

The safety limit for track irregularities cannot be determined uniformly due to the complexity of operating conditions, adjustment conditions of rolling stock, compound conditions of track irregularities, etc. According to the result of investigation by a certain accident investigation committee in Japan, the safety limit for conventional lines is determined at +43 mm/-13 mm for the gauge, ±40 mm for the unevenness, ±36 mm for the alignment, and ±27 mm for the twist. As the safety control standard values for urgent adjustment, on the other hand, 20 mm for the gauge, 23 - 30 mm for the unevenness, 23 - 30 mm for the alignment, and 23 mm for the twist are adopted.

These values are nearly twice as loose as the maintenance target values.

For the Shinkansen, from the viewpoint of riding comfort, 0.35 g for the vertical acceleration vibration, and 0.25 g for the transversal acceleration vibration are adopted for the standard values. In determining the safety control standard values, it is recommended to determine the target value from the view point of the riding comfort like the case of the Shinkansen, considering the high train speed.

(2) Maintenance system

The track maintenance between Ghaziabad and Kanpur is done manually and with a TTM (Tie Tamping Machine) at present. Overall tamping with two TTMs is done every 15 months for the standard of accumulated passing tonnage of 50 GMT. On the Section, a drastically increased number and speed of trains is expected in the future, and in spite of a new track structure, it is envisaged that the maintenance work volume will grow about 80% by 2,000 from the present. (See Appendix 4-21.) On the other hand, it will become more difficult to secure maintenance block time, and to work while allowing train operation owing to the increased train speed. To maintain the track in a good condition, therefore, the improvements of the maintenance system mentioned below will be necessary.

1) Employment of periodical repair system

In parallel with preparation of the said maintenance standard values in 3 categories, mechanical power is employed for track maintenance work. It can realize periodical maintenance and contribute to maintaining tracks in a good condition and raise the maintenance work efficiency.

2) Employment of mechanical maintenance

a) Employment of TTM

TTM should be employed both for overall tamping and raising. For this purpose, one TTM should be provided for each Sectional PWI.

According to a typical example in Japan, in a section of over 30 GMT per year, overall tamping is performed every 2 years, while raising is done every 6 months by one TTM. In the Section, however, more frequent work will be needed, so the required number of TTMs is calculated below.

The work capacity of one TTM is about 500 m per hour when used for overall tamping with double tool, and about 1,000 m per hour for raising. The work time for overall tamping is 826 h,

(413 km x 2 (double track) ÷ 2 ÷ 500 m/h = 826 h)

while the time needed for raising is 1,652 hours. Therefore, about 2,480 hours are needed in total. The maintenance block in the Section is 2 hours in general. Considering the time necessary for moving to the maintenance location and preparation, the actual time allowed for maintenance work is about one hour. Taking 260 working days per year, the number of TTMs needed for this section is estimated to be 9.

b) Employment of other machines

For performing mechanized maintenance, in addition to TTM such machines are needed as:

Ballast regulator, Ballast compactor, Ballast sweeper, Ballast cleaner, Portable tamper, Portable ballast compacter, various Trolleys, Track motorcar, Maintenance automobile

c) Upgrading of stumbling track for maintenance machines

On the Section, stumbling track for maintenance machines is prepared for every 20 - 30 km interval at present. For the expected future increase in the number of maintenance machines and work volume, a stumbling track should be prepared at every station so that the transfer time is reduced and the operation time of machines is maximized.

6-2-2 Signalling and Telecommunication

(1) Automatic Inspection Car for Electric Equipment

1) Necessity

At present, the most of the facilities are located in station compounds. In this Project, a jointless audio frequency track circuit, wayside device of AWS, and automatic level crossing equipment will be installed in the section between Ghaziabad-Kanpur. In addition, the high-speed, and high-density train operation is expected to make it considerably difficult to secure a sufficient maintenance interval. To cope with this situation, therefore, it is necessary to devise a measure to inspect signalling facilities in the state of operation without being affected by the availability of the maintenance interval. In this context, automatic inspection car for electric equipment could be introduced as one of the countermeasures.

2) Outline

The automatic inspection car for electric equipment is equipped with measuring equipment and data processors. It runs and checks the function of the ground facilities such as signalling equipment and overhead contact wires, and processes the measured data on board. Namely, in addition to improving the inspection efficiency, it can analyze the measured data to upgrade the maintenance quality. For reference, the automatic inspection car for electric equipment used in Japan is described in Appendix 5-13.

(2) Wireless communication equipment and automobiles for maintenance work

1) Necessity

At present, when maintainers need to hurry to a field spot for maintenance or failure recovery, it takes fairly long time to arrive at the spot because transportation means are limited to walking, train, or trolley. The communication facility currently available in the field is only a portable magneto telephone connected to the tap of an instrument box.

However, in the future, greater efficiency of maintenance and quicker restoration will be required to cope with the high speed and high density train operations as well as greater volume of inter-station facilities. In order to meet this requirement, it is necessary to provide better maneuverability and more convenient communication means. There will exist the same need for improving the maneuverability and communication means of Elect. and Engg. sections as S&T section.

2) Automobiles and motorcycles for maintenance purpose

Jeeps and motorcycles should be suitably distributed according to the maintenance territory and number of personnel.

3) Maintenance portable wireless

Portable wireless should be provided to ensure maintenance work and failure-recovery in the field where a communication tool such as a portable magneto telephone can not be used.

For example, in JR one automobile and one set of portable wireless are provided for a maintenance gang in charge of about 10 km of double-track electrified section with 5 or 6 maintenance personnel.

(3) Maintenance of electronic equipment

1) Features of maintenance of electronic devices

This Project employs various electronic devices in the signalling and telecommunication system.

Electronic parts, particularly semiconductors, used for electronic devices are operable under certain environmental conditions owing to the natures of their materials. Therefore, selection of devices and circuit design should be made after careful investigation of the predetermined operating conditions. In operation, it is necessary to check if the predetermined operating conditions are maintained.

The failure distribution curve of the electronic device looks like a bath tub (Fig. 6.2.2-1). Initial failures should be removed as completely as possible through the aging operations to be made before regular operation. And as the equipment renewal is to be made in the wearing failure period, maintenance will be executed mainly for random failures. How to cope with such failures is a subject of maintenance.

Since many electronic devices are operating with high-speed pulses of micro-current in complex circuits, a maintenance crew knows only the operating conditions of each unit, and a inside of the unit is like a so-called "black box" to them.

How the electronic equipment is to be maintained should be studied taking the aforementioned points into consideration.

Typical Instruments for repair and measurement are described on Appendix 5-23.

2) Maintenance system

Generally, maintenance systems can be roughly divided into two categories. One is a preventive maintenance to be used before a failure occurs. The other is to make a repair when a failure occurs. The latter is called corrective maintenance. Preventive maintenance is desirable to minimize the occurrence of failures. However, its application to electronic devices is impossible because of their random failure distribution. However, as a total system including a power unit which needs preventive maintenance, both corrective and preventive maintenance services are required in practice. (Fig. 6.2.2-2)

3) Method of corrective maintenance

Attention should be paid to the following points in corrective maintenance.

a) A system of quickest possible restoration should be established so a failure can be repaired as early as possible.

b) An important facility should be constituted so that the vital function can continue operation even if a failure should occur at a part of it. (Design condition)

c) Failures, if any, should be analyzed to study the causes, so improvement may be fed back to the manufacturing, construction or maintenance sector to reduce the similar failures.

d) Failure data should be analyzed to judge whether the wearing failure period is reached. A replacement plan should be made as early as possible, if necessary.

For quick restoration from a failure, it is most important to minimize the time needed for troubleshooting, and the following points are requested.

a) Maintenance crew, well trained for circuit composition of the facilities and possible troubles, should be posted.

b) The devices should have the functions of detecting, diagnosing and indicating the location and cause of a failure automatically.

As to a), however, it may be difficult to employ many experienced and learned maintenance crews, especially when so many items of new technology are introduced at a time. Therefore, it is necessary to equip facilities with failure detection/indication functions so failures can be easily located and repaired. There is a certain limit in automatic failure detection, of course, and it is impossible to have all failure conditions of every component clearly displayed. Maintenance crew, therefore, are requested to acquire knowledge to such a level that they can locate a failure and condition from failure display.

For repair of failures that might occur in facilities located between stations, traffic measures and a telecommunication system should be well prepared to enable maintenance crew to arrive at the site of failure as quickly as possible and work under well organized communication facilities. Data of failure is very important and useful for future maintenance and improvement of facilities. Accordingly, a format should be designed so all necessary items can be recorded, and the system should be so designed that the information can be conveyed without fail to all posts concerned. As an example of the format, a format of Report on Defective Devices of Shinkansen is shown in Appendix 5-11.

Analyses of such data facilitate improvement of maintenance method and equipment, and judgment of replacement period.

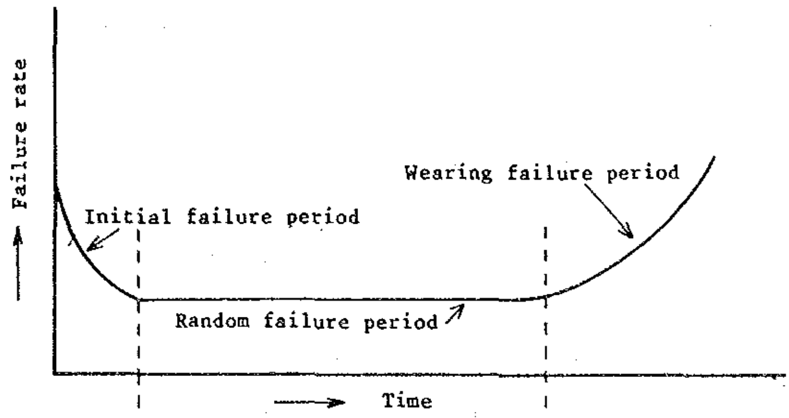


Fig. 6.2.2-1 Failure Distribution of Electronic Devices

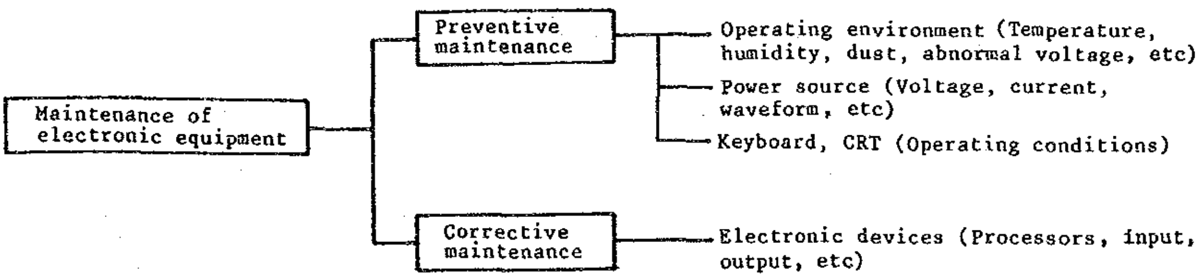


Fig. 6.2.2-2 Maintenance Methods of Electronic Equipment

(4) Remote monitoring system

1) Purpose of remote monitoring system

The purpose of this system is to prevent failures of the facilities and to shorten the repair time by following functions:

a) Detection of a deteriorated function and generation of an alarm.

b) Detection of a facility failure and generation of an alarm.

2) Facilities to be monitored by remote monitoring system

The facilities to be monitored by this system are as shown in Appendix 5-17. These facilities should be selected considering the allocation and technical level of maintenance crew. Alarms may be classified and indicated in two categories: cases where, upon the occurrence of an alarm, maintenance crew should immediately rush to the site for remedy (serious failure), and cases where there is fairly much time till some remedy should be devised after an alarm (slight failure).

3) Construction of remote monitoring system

A construction example of the remote monitoring system is shown in Appendix 5-17. Between Ghaziabad and Kanpur, the failure information of facilities located between stations is transmitted to the station by the underground communication cable, then to the dispatcher center through the train traffic control system.

(5) Improvement of reliability of signal lamp

Necessity of improvement of reliability

For high-speed, high-density train operation, upgrading signalling facilities is prerequisite. The more the upgrading progresses, the more seriously the traffic will be affected once a failure should occur. Therefore, adequate maintenance is required to prevent failure of the facilities, or for early corrective measures upon the occurrence of a failure. However, it is more important to improve the reliability and the life of every facility itself so that it may become failure-free and maintenance-free. For such a purpose, designers, manufacturers, and maintenance crews are requested to cooperate in information exchange, development, and improvement.

Signal lamps, fuses, and other parts which are used in signalling facilities in a large number do not appear to be very reliable in Indian Railways. Especially, any failure that should happen in such parts used in automatic signalling devices between stations would need a lot of time for repair, seriously affecting train operation.

For reference to future improvement of such parts, Japanese Railways' experience in both improvement and digest of standards for signal lamps are described in Appendix 5-12.

6-2-3 Electrification

(1) Substation (SS)

Six more substations are to be added under IR's Project. Therefore, maintenance work will double. However, the composition of each of these substations is to be the same as that of existing substations, and no change in their maintenance method. What is better, the SS interval will be shortened, extended feeding easier to provide, and SS maintenance also easier to perform.

As for the existing SS equipment, the problem is the maintenance of CB and interrupter because CB trips frequently. Urgent efforts must be made to reduce the number of trippings for decreasing the maintenance work, keeping the equipment from deteriorating and also its reliability from lowering.

In JR, the movable automatic inspection device equipped with microprocessor is in use to efficiently check and maintain the switch board interlock and relays, and also control figures and values. For reference, Appendix 6-8 outlines the device. To apply this device to the existing switch board, the connection of which must be modified, however.

(2) Maintenance of Overhead Equipment

Increased number of trains and their speeds will bring about the increased pantographs number passing through the OHE system and also the number of repeating vibrations to it.

The former will accelerate the wear of contact wire, and the latter will cause the untightness of metallic fixtures. An equipment trouble, even for a short while, that takes place on the heavily densed section will affect many services. Therefore, the inspection of equipment will become all the more important.

On the other hand, the conditions of maintenance will worsen. In other words, additional and faster trains will make it more difficult to secure enough maintenance time between train intervals.

As for maintenance schedules for OHE, IR's manual of maintenance provides that foot patrolling shall be performed once a forthnight, trolley inspection once a month, current collection tests once in 3 months. In addition, inspection cycles for special checks are set forth on every equipment.

To conduct those inspections under the aforementioned circumstances, it is suggested to introduce an electric equipment inspection car in order to improve efficiency and effectiveness of maintenance work.

It is required for the electric equipment inspection car to be capable of checking on the following items:

i) Height of contact wire
ii) Stagger of contact wire
iii) Gradient of contact wire
iv) Abrasion of contact wire
v) Obstacles in the way of the pantograph driving
vi) Hard spots

The electric equipment inspection car used in JR is outlined in Appendix 6-15.

6-3 Ground Facilities of the New Corridor

6-3-1 Maintenance Block

High-speed trains are operated in the New Corridor. Therefore, from the viewpoint of security assurance for maintenance work and higher accuracy/efficiency required for the maintenance work, it is recommended to adopt mechanized intensive maintenance. To realize this, it is necessary to secure time zone exclusively used for maintenance work as shown in Fig. 6.3.1-1. During this time zone, maintenance work for the all ground facilities is executed.

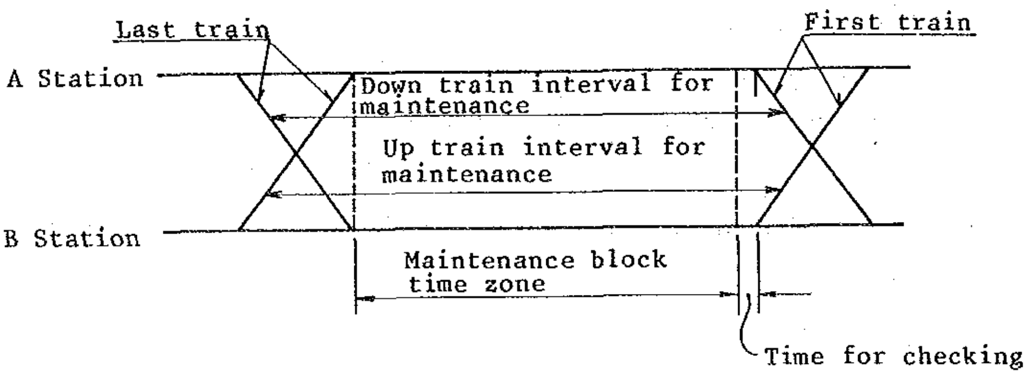


Fig. 6.3.1-1 Train Interval and Maintenance Block Time Zone

In Shinkansen, approximately 5 hours of maintenance block is secured for daily maintenance work. Assuming that maintenance work of the same level are needed for the New Corridor, approximately 4 hours maintenance time will be necessary, considering 2 hours for actual work, and 2 hours for on-rail transportation of maintenance machines from the depots, work preparations, adjustment of machines, and clearance after work.

Since the high-speed operation begins with the first Shinkansen train, checks after maintenance are made by a track morter car. It is recommended to execute checks after maintenance in the same manner on the New Corridor.

6-3-2 Maintenance Work Control

Maintenance work on the New Corridor will be executed using various work trains and maintenance machines during a maintenance block time zone as stated in CHAPTER 6-3-1. Therefore, it is necessary that a wide range of such maintenance works as start of work, operation of maintenance machines, and completion checks should be carried out systematically among various systems. In Shinkansen, various dispatchers specialized in such fields as train operation, permanent way, electrification, and signalling & telecommunication control, under close coordination, various maintenance works from the control center.

It is considered necessary to provide a similar system for the New Corridor for assurance of safety in train operation, and security of maintenance works.

6-3-3 Track Maintenance

(1) Maintenance system

Maintenance work will be executed during the maintenance block time zone at night using large scale mechanized maintenance cars. Track renewal and adjustment of track irregularities are basically to be made in the manner of periodical maintenance, while emergency adjustment of track should be performed in the manner of non-periodical maintenance.

(2) Track control

1) Target values of maintenance

In view of the maximum 250 km/h high-speed train operation, it is recommended to establish target maintenance values to assure safety and riding comfort. Like the maintenance method of the Section described in (1) of CHAPTER 6-2-1, it is recommended to provide standard control values in 3 stages such as target values for track work and adjustment, standard maintenance values for preparing maintenance plans considering riding comfort, and standard safety control values urgently needed for safety.

For reference, the control target values for Shinkansen are shown in Appendix 4-20.

2) Track inspection system

The track inspection items currently used in IR are considered good enough to be applied for the New Corridor. Dynamic inspection by a high-speed track inspection car will mainly be employed for inspecting tracks. Although 10 days of Shinkansen's inspection cycle is considered adaptable for the New Corridor, a final decision should be made after observation of the progress of the track irregularities by actual train operations on its model test line.

(3) Maintenance organization

The maintenance organization should be prepared in accordance with the circumstances of Indian Railways. It is proposed, however, that the New Corridor be administered with three track maintenance centers. Each center will be provided with three branches. Each branch will have one maintenance depot for storage and repair of mechanized maintenance cars.

(4) Maintenance depot

Nine maintenance depots will be located every 50 km. Works executed at maintenance depots are as follows:

- Renewal works of continuous welded rails, turnouts, and ballast.
- Periodical ballast tamping.
- Periodical raising and alignment work.
- Emergency repair work.

A party organized with maintenance machines will efficiently carry out the abovementioned maintenance works. Combinations of major maintenance work and maintenance machines are shown in Table 6.3.3-1.

One out of three Maintenance Depots will be renewal work depot specialized for material renewal and track maintenance. The other two maintenance depots should function as ordinary work depots for track maintenance. The renewal work depot will be furnished with facilities for inspection and repair of maintenance machines. Every depot should be provided with storage tracks for electric maintenance cars. Model layouts are shown in Fig. 6-3-3-1. One of the renewal work depots should be provided with a welding depot for continuous welded rails.

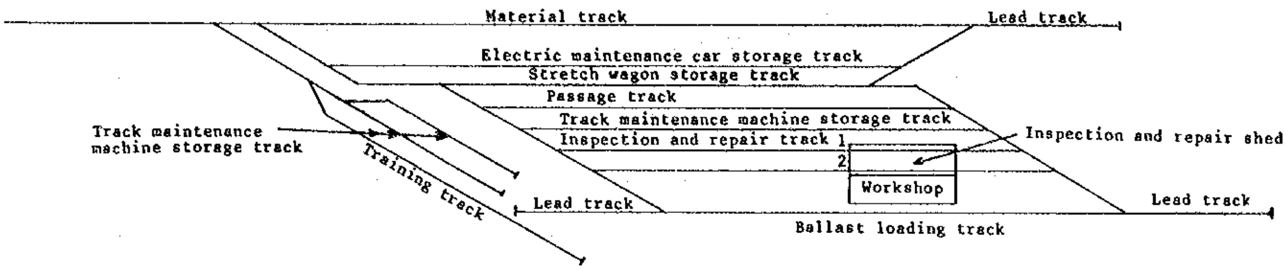
Table 6.3.3-1 Major Maintenance Work and Maintenance Machines

Kind of work	Make-up of maintenance machines
Renewal of continuous welded rail	. (D.L) + (R.C.C) + (B.V) + (T.M.C) + (R.C) + (M.P.W) + (W.M.C)
Renewal of ballast	. (D.L) + (H.W) + (B.V) + (T.M.C) + (B.Rm) + (T.T.M) + (T.L) + (B.R) + (V.C) . (D.L) + (H.W) + (B.V) + (M.P.W) + (T.T.M, Y.T) + (T.L) + (B.R) + (V.C)
Overall tamping and raising	. (M.P.W) + (T.T.M, Y.T) + (T.L) + (V.C)

Note

D.L:	Diesel locomotive
R.C.C:	Rail carrying car
B.V:	Brake-van
T.M.C:	Track morter car
R.C:	Rail changer
M.P.W:	Multiple power wrench
W.M.C:	Welding machine car
H.W:	Hopper wagon
B.Rm:	Ballast remover
T.T.M:	Tai Tamping Machine
T.L:	Track liner
B.R:	Ballast regulator
V.C:	Vibrating compactor
Y.T:	Yard Tamper

Renewal work depot



Ordinary work depot

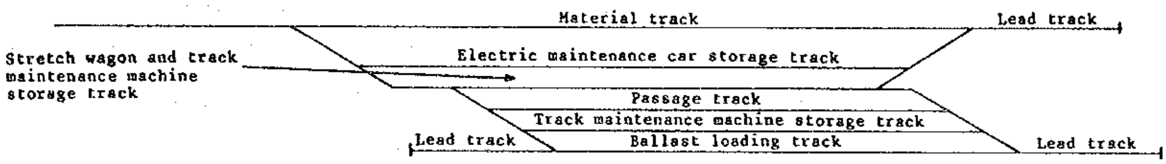


Fig. 6.3.3-1 Maintenance Depot

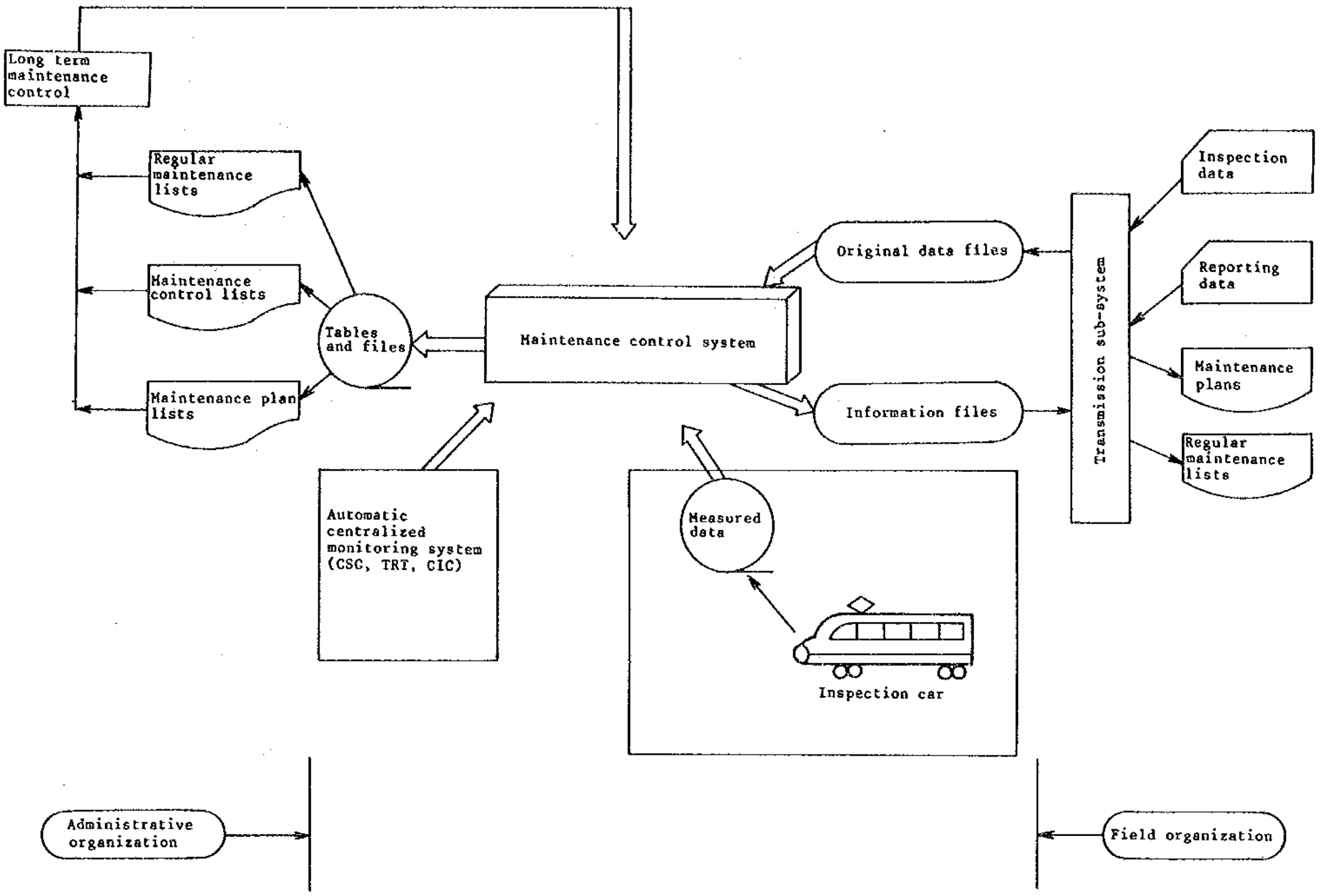
6-3-4 Signalling and Telecommunication

To improve efficiency of maintenance works and safety of electric facilities, it is necessary to collect and analyze failure data and maintenance data of the related facilities so that maintenance man-power and expenses can be reallocated accordingly.

Since the New Corridor is operated at high-speed and high-density the maintenance interval is extremely limited, and the occurrence of a failure, if any, may seriously affect the train operation.

On the other hand, unlike the conventional line, it is easy to control electric facilities because of uniform timing of the completion of installation. Consequently, in order to accomplish more efficient maintenance of the signalling and telecommunication facilities, the conventional manual maintenance method should preferably be replaced by new maintenance system which includes an automatic centralized monitor system and an automatic inspection car for electrical equipment. (See Fig. 6.3.4-1)

The arrangements should be made so that various original maintenance data promptly processed by the central computer, and maintenance control data (statistics of failures list of facilities, operating record, etc.) and replacement & repair plans of facilities can be obtained timely through terminals in the field. The Shinkansen Management Information System operating for the Shinkansen is described in Appendix 5-14.



CIC: Centrized Information Control
TRT: Train Radio Tester
CSC: Centralized Substation Control

Fig. 6.3.4-1 Outline of Maintenance Control System

6-3-5 Electrification

(1) Substation (SS)

Basically, the maintenance of substations on the New Corridor is the same as that of those on the Section, though the equipment capacity of the former is larger than that of the latter.

In the case of AT feeding system, autotransformers are to be installed at substations, sectioning posts and sub-sectioning posts, but they are not different from conventional transformers from the maintenance point of view.

If a supervisory remote control device as shown in Appendix 6-2 is applied, the maintenance of substation will become easy, thus achieving high system reliability.

(2) Maintenance of Overhead Equipment

a) Necessity

Overhead equipment being of single system, preventive maintenance service is required.

The equipment will deteriorate in the following two occasions:

i) when reaching the end of service life and;

ii) when temporarily exceeding a permissible value of stress, load, etc.

Mainly, service life control method will be applied to those which will cease to function for the reason i), and limit value control method of preventive maintenance for the reason ii).

As for the contact wire, the most important equipment, it is suggested that an electric inspection car be put into service and application of both the service life control and the limit value control methods.

The reasons for this are 1) that the wear of contact wire will gradually worsen as its working time increases, ceasing function in the end; and 2) that the height and stagger of contact wire have their limit values.

b) Method

Repair works will be performed during the time zone by using maintenance work cars.

Table 6.3.5-1 shows the features of maintenance work cars of the Shinkansen:

Table 6-3-5.1 Principal Features of Maintenance Work Cars

Items \ Name / Abbreviation	Stretch car	Tower car	Revolving car	Crane car
	SW	TW	RW	CW
Rating output of engine (KW)	136	136	136	136
Body length between couple (mm)	8,350	8,350	9,050	9,050
Body weight (t)	22	17	24.5	26
Maximum hauling load (t)	20	-	25	25
Maximum running speed (km/H)	70	70	70	70
Maximum lifting load of crane (t)	2.9	-	2.0	4.8
Ascend and descend, rotation of working base	Available for ascend and descend	Available for ascend and descend	Available for ascend, descend, and rotation	Attachable, detachable
Kinds of works	.Extension of wires .Winding of wires .Exchange of metallic fixtures for catenary line	.Exchange of hangers, dropers, and hinged pull-off arm .Exchange of other metallic fixtures for catenary line	.Exchange of bracket cross arm .Exchange of metallic fixtures for catenary line	.Replacement of poles .Exchange of portal, transformers, and others .Exchange of metallic fixtures for catenary line

The above maintenance works cars after completion of construction works, are also used as inspection cars for the facilities.

c) Inspection

It is recommended that preventive maintenance method be provided based on the dynamic inspection data collected by the electric inspection car.

JR's electric equipment inspection car which is operated once a week on the whole section is outlined in Appendix 6-15.

d) Organization

A proposed plan is to divide the New Corridor into 3 maintenance section, each section having three maintenance depots with a maintenance base to accommodate service cars.

CHAPTER 7 ECONOMIC ANALYSIS

CHAPTER 7 ECONOMIC ANALYSIS

7-1 Cases for Analysis and Analysis Period

7-1-1 Cases for analysis

(1) Case (A) : With .... Upgrading the existing Section between Delhi and Kanpur

Without .... No project

(Case A is set up to analyse feasibility of the upgrading project)

(2) Case (B) : With .... Constructing the New High-Speed Corridor between Delhi and Kanpur via Agra after upgrading the Section

Without .... Upgrading the Section

(Case B is set up to analyse feasibility of the New Corridor construction project which assumes implementation of the upgrading project in advance)

(3) Case (C) : With .... Upgrading the Section and constructing the New High-Speed Corridor

Without .... No project

(Case C is set up to analyse overall feasibility of the both upgrading project and the New Corridor construction project)

7-1-2 Analysis Period

Case (A) 37 years

1988	Start of upgrading
1990	End of upgrading
1991	Inauguration of the upgraded facility
2024	End of analysis period

(Note) The final year of the analysis period shall fall upon the final year of Cases (B) and (C).

Case (B) 30 years

1995	Start of construction
1999	End of construction
2000	Inauguration
2024	End of analysis period

Case (C)	37 years
1988	Start of upgrading the existing Section
1990	End of upgrading
1991	Inauguration of the upgraded facility
1995	Start construction of the New High-Speed Corridor
1999	End of construction
2000	Inauguration of the New High-Speed Corridor
2024	End of analysis period

7-2 Objective

The objective of the economic analysis is to analyze and evaluate these projects from standpoint of national economy.

7-3 Method of Economic Analysis

The costs and economic benefits of both implementing the project ("With the Project") and not implementing the project ("Without the Project") are analyzed and compared, and the Economic Internal Rate of Return (EIRR) is then calculated as an index for evaluating the viability of the project.

The costs consists of the investment and operating costs, and the benefit consists of the passenger time saving.

The EIRR is the discount rate which would make the present value of the costs equal to the present value of the benefits. The EIRR is calculated as follows:

$$0 = \sum_{i=1}^{n} Ai/(1+EIRR)^{i-1}$$

where:

n : Project life

Ai : Differences of investment and operating cost between "With the Project" and "Without the Project" plus the benefit of implementing the project in each year

Table 7.3-1 EIRR analysis items

Item	With the Project	Without the Project
Investment	Railway facilities Rolling stock	Buses, trucks, & airplanes
Cost	Railway maintenance cost Railway personnel cost Railway electric power cost	Buses, trucks, & airplanes maintenance cost Buses, trucks, & airplanes Personnel cost Buses, trucks, & airplanes power & fuel cost
Benefits	Railway passenger transport time	Railway passenger transport time Buses & airplanes passenger transport time

7-4 Premises

7-4-1 Traffic volume and investment

The relationship between traffic volume and railway investment, the details of which are given in Chapter 3 (3-2), Chapter 4 (4-6) and Chapter 5 (5-7) respectively, is stated as follows:

(1) With the Project
Investment in the railway sector to provide the facilities and rolling stock required to carry the diverted traffic volume from buses, trucks, and airplanes and the induced traffic volume to railway as a result of implementing this project.

(2) Without the Project
Investment to purchase buses, trucks, and airplanes required to carry the traffic volume that would be diverted to railway transportation in the "With the Project" case.

7-4-2 Exchange rate

Rs. 1 = Japanese Yen 11.35 (As of June 1987)

7-4-3 Economic price

Price subtracting tax, that is regarded as transfer item from the standpoint of the national economy, from the market price as of June 1987 (economic price) is used in this study. The price is fixed for the period of analysis.

7-4-4 Reinvestment

The same amount of initial investment of depreciable assets is reinvested in the year following the expiration of its useful life.

7-4-5 Residual value

The unamortized portion of depreciable assets and a half of the replacement assets, as residual value, will be counted as negative investments.

7-4-6 Inflation

Inflation is not considered in the analysis, for it is virtually impossible to forecast the inflation rate for the 37-years period.

7-4-7 Diversion of electric locomotives and coaches

The residual value of the surplus electric locomotives and coaches diverted from the Section to other sections will be counted as a negative investment at the opening year of the New High-Speed Corridor.

7-5 Investment

7-5-1 Investment items

In the "With the Project" case, investment items in the railway sector include track and structure, signaling & telecommunications facilities, power substations, electric facilities, rolling stock, and land, which will be stated in detail in Chapter 4 (4-6) and Chapter 5 (5-7).

In the "Without the Project" case, investment items include buses, trucks, and airplanes which would be required for transporting the diverted traffic volume from each transporting mode to the railway in the "With the Project" case. The required number of vehicles and investment are calculated by the following equation.

Required number of vehicles = Annual diverted traffic volume (person-km or ton-km) ÷ Average annual transport volume (person-km or ton-km) per vehicle

(Note: Number of vehicles is rounded off)

Diverted traffic volume from buses, trucks and airplanes to railway and average annual transport volume per vehicle are shown in Table 7.5.1-1 and Table 7.5.1-2.

Table 7.5.1-1 Traffic Volume to be Diverted from Bus, Truck, and Airplane to Railways

(Unit: 1,000 passenger-km or 1,000 ton-km)

	Year	Bus	Truck	Airplane
Case (A)	1991	1,084,017	906,516	680
	1995	3,438,928	4,806,450	2,914
	2000	7,528,183	11,786,292	8,004
Case (B)	2000	12,222,369	0	1,833,297
	2005	18,375,313	5,538,051	2,811,333
	2010	25,383,221	12,275,595	4,040,402
Case (C)	1991	1,084,017	906,516	680
	1995	3,438,928	4,806,450	2,914
	2000	20,611,540	11,786,292	1,833,297
	2005	27,115,765	17,324,343	2,460,052
	2010	34,551,501	24,061,887	3,261,292

Table 7.5.1-2 Average annual transport volume per vehicle

Bus	3,528,000 person-km
Truck	456,000 ton-km
Airplane (B-737)	217,776,000 person-km

(Note) The airplane type operated in the project area is Boeing 737.

The following data for buses, trucks, and airplanes are based on information provided by the Road and Surface Transport Department, Ministry of Civil Aviation/Indian Airlines, and RITES as well as from the analysis of the Operational Statistics of D.T.C. (Delhi Transport Corporation) 1986, Annual Report 1985 - 1986 of Indial Airlines, and other information from pertinent institutions.

<u>Bus</u>:

Capacity	60 persons
Average occupancy ratio	84%
Useful life	8 years
Traveling distance	70,000 km/year
Price	Rs. 235,471 /unit

<u>Truck</u>:

Loading capacity	10 tons
Average load factor	76%
Useful life	10 years
Traveling distance	60,000 km/year
Price	Rs. 155,036 /unit

<u>Airplane (B-737)</u>:

Capacity	130 persons
Average load factor	69.8%
Useful life	10 years
Traveling distance	2,400,000 km/year
Price	Rs. 327,500,000 /unit

Note: The prices are all economic prices.

7-5-2 Economic price adjustment

(1) Railway

1) Foreign currency portion

The CIF price is adopted. customs duty, auxiliary duty, and countervailing duty are not included.

2) Local currency portion (materials & facilities)

The price obtained by subtracting the excise duty and sales tax from the market price is regarded as the economic price.

An average tax rate of 24% for materials and facilities is used to calculate the economic price.

3) Local currency portion (personnel cost)

No tax adjustment is required for the personnel expenditures because the wage of the average worker is estimated to be below taxable income.

The allowable deductions from income tax are Rs. 18,000 per year as of the survey timepoint.

(2) Bus, truck and airplane

1) Bus and truck

The price obtained by subtracting the average excise duty (30%), average sales tax (8%), and registration fee (Rs. 50) from the market price is regarded as the economic price.

2) Airplane

The CIF price of the Boeing 737 operated in the project area is regarded as the economic price.

7-6 Operating Cost

7-6-1 Railway

(1) Maintenance cost

Calculation method of annual maintenance cost

Depreciable assets maintenance cost = Total investment of depreciable assets x Maintenance rate

Replaceable assets maintenance cost = Total investment of replaceable assets x Maintenance rate

Replaceable assets replacement cost = Total investment of replaceable assets x replacement rate

Note: a) Depreciable assets are those assets of which the values are annually depreciated and for which reinvestment is made after the completion of the useful life.

Replaceable assets are those assets which are partially replaced annually at a predetermined rate, so that the assets are continually renewed.

b) Classification of depreciable/replaceable assets, maintenance rate, replacement rate, and useful life is based on the standard data of JR (See Table 7.6.1-1).

Table 7.6.1-1 Maintenance & Replacement Rate and Useful Life of Railway Assets

Items	Assets description	Maintenance rate	Replacement rate	Useful life (year)
Civil work	Roadbed	0.0004		57
	Road bridge	0.0027		50
	Platform	0.0041		32
	Overbridge	0.0051		32
	Station building	0.0067		45
	Building (workshop depot etc.)	0.0057		45
	Track	0.006669	0.04446	25
Signalling & telecommunication	Level crossing facilities	0.0292		12
	Signalling facilities	0.0210		20
	Telecommunication facilities	0.0312		9
	Signalling cable	0.0011114	0.0317571	35
	Telecommunication cable	0.0038108	0.0317571	35
	Track circuit	0.0020475	0.0585	19
Electrification & power supply	Substation facilities	0.0008		20
	Substation building	0.0057		45
	Overhead equipment	0.000741	0.0247	45
	Power distribution line	0.0055575	0.03705	30
Rolling stock	Electric locomotive	0.0407		30
	EMU	0.035		20
	Coach	0.02178		30
	Wagon	0.0147		30
	Machinery at workshop	0.05		20
	Machinery at depot	0.05		20

(2) Personnel cost

The annual personnel cost for each job is calculated by multiplying the number of personnel added in the project by the average annual wage.

The number of personnel added in the project is shown in Appendix 8-7.

The added number of personnel for each job is estimated based on the performance of IR and the Shinkansen of Japan.

Average annual wage for each job is estimated based on data submitted by IR and is adjusted to the economic price.

Table 7.6.1-2 Average annual wage of the railway employee for each job (economic price)

(Unit: Rs)

Job	Annual wage
Driver	27,672
Conductor	17,772
Station staff	17,856
Maintenance staff	17,856
Head office staff	19,644

(3) Electric power cost

The electric power cost is calculated as follows:

Annual electric power cost = Annual transport ton-km
x Electric power consumption rate per ton-km
x Unit price of electric power

Table 7.6.1-3 Electric power consumption rate

(Unit: KWh/1,000 ton-km)

Type of train	Power consumption
Super Express	36.9
Long Express	18.8
Express Mail	18.8
Local	25.7
Freight	10.0

Note: The electric power consumption rate of the S. Exp. is estimated based on the JR data and those of L. Exp., Exp. Mail., Local and Freight trains on the data of IR.

Unit price of electric power: Rs. 1.004 /kwh

Note: Based on the IR data

7-6-2 Bus, truck, and airplane

The average annual maintenance and operating cost of bus, truck, and airplane are calculated by the following equations.

Maintenance cost = Annual number of vehicles x Annual average traveling distance per vehicle x Unit cost price (Rs/km)

Fuel cost = Annual number of vehicles x Annual average traveling distance per vehicle x Unit cost price (Rs/km)

Personnel cost = Annual number of vehicles x Annual personnel cost per unit

The average maintenance and fuel cost per vehicle-km of bus, truck, and airplane, and the annual personnel cost per unit are as follows.

The data is also based on the source mentioned in 7-5-1.

Table 7.6.2-1 Unit cost of bus, truck and airplane (economic price)

	Maintenance cost	Fuel cost	Annual personnel cost
Bus	Rs 0.68/km	Rs 0.56/km	Rs 77,700/unit
Truck	Rs 0.98/km	Rs 0.59/km	Rs 50,000/unit
Airplane	Rs 6.38/km	Rs 30.16/km	Rs 198,800/unit

Maintenance cost includes engine oil and tire cost. Maintenance cost and fuel cost are regarded as the economic price given by subtracting excise duty and average sales tax from the market price. Personnel cost is also regarded as the economic price given by subtracting personnel income tax.

The market price and economic price of diesel oil, engine oil, air-craft fuel and tire are shown in Appendix 8-8.

7-7 Passenger Time Saving Benefit

7-7-1 Evaluation of the passenger time value

The average income of passengers is assumed nearly at the same level as earnings of industrial workers, with reference to general statistical materials, fare level of the IR and information from relevant institutions.

The average annual earnings per capita of industrial workers is Rs. 7,470 in 1982 and is estimated to be Rs 12,000- (Rs 1,000/month) in 1987 by adjusting with the growth rate of the consumer price index.

(Source: Indian Labour Year Book 1985
Economic Survey 1985-86)

Accordingly, the passenger time value is calculated as follows:

Passenger time value = Monthly earnings per passenger/
Average monthly working time
x Non-working time adjustment factor

Monthly earnings per passenger: Rs.1,000

Average monthly working time : 182 hours

Note: Normal working hours of industrial workers are 8 hours a day for 273 days in a year.

(Source: Statistical Outline of India 1986-1987)

Non-working time adjustment factor: 0.75

Note: Assuming the activity time per day at 12 hours, the time value of non-working hours is assumed to be one fourth of that of working hours.

Accordingly, the time value of passengers is Rs.4.12

Also, it is supposed that the time value would increase in proportion to the growth rate of GDP per capita.

Note: The growth rate of GDP per capita up to the year 2000 is taken from the 7th Five Year Plan and that after 2000 is calculated from the estimated population and GDP growth rate of 4%. (See Table 3.1.3-8, 3.1.3-9.)

7-7-2 Calculation of passenger time saving benefit

The benefit of passenger time saving is given by the following equation.

Passenger time saving benefit
= Passenger time value x Saving in passenger time

Saving in passenger time, that is reduction in transport time due to diversion from other transport modes to railway, is calculated based on the demand forecasts.

Saving in passenger time is shown in Table 7.7.2-1.

Table 7.7.2-1 Time to Be Saved by Passengers

(Unit: 1,000 passenger-hours)

	Year	Passenger-hours
Case (A)	1991	20,442
	1995	45,645
	2000	89,396
Case (B)	2000	255,841
	2005	358,776
	2010	484,578
Case (C)	1991	20,442
	1995	45,645
	2000	379,869
	2005	490,882
	2010	626,525

7-8 Results of Analysis

7-8-1 EIRR

Based on the differences of investment and operating cost between "With the Project" and "Without the Project", and the benefit of time saving, EIRRs are calculated by computer model, the results of which are shown in Table 7.8.1-1.

(See Appendix 8-1, 8-3 and 8-5 for details).

Table 7.8.1-1 EIRR

(%)

Case	Case (A)	Case (B)	Case (C)
EIRR	42.62	24.09	36.08

As for the fare of the Super Express train of the New High-Speed Corridor, 5 fare levels are set at higher level by 0, 25, 50, 75, and 100% than that of 2nd class Mail/Express train of the Section, and demand forecasts are made for respective fare levels. Respective EIRRs and FIRRs are calculated and the results are shown in Table 7.8.1.2.

In this study, the base case means the case that the fare structure of the Super Exp. train of the New Corridor is set at higher level by 25% than that of 2nd class Exp./Mail train of the Section.

Table 7.8.1-2 EIRR & FIRR Calculated by Respective Fare Level

EIRR & FIRR

(%)

Case	EIRR	FIRR
Case (B)		
Fare 0% up	26.76	7.47
25% up	24.09	9.86
50% up	19.91	9.97
75% up	16.65	8.26
100% up	14.96	6.75
Case (C)		
Fare 0% up	37.28	16.81
25% up	36.08	18.00
50% up	34.38	18.12
75% up	33.16	17.48
100% up	32.59	16.93

Fare levels

(Unit: Rs/pass-km)

Fare up (%)	Fare
0	0.11
25	0.14
50	0.17
75	0.19
100	0.22

7-8-2 Sensitivity Analysis

In the economic analysis, sensitivity analysis are usually conducted from pessimistic point of view concerning diverted traffic and investment. In this analysis, the sensitivity analysis in the case of a 2-year extension of the construction period and a 50% reduction in passenger's time value are also conducted. The results are shown in Table 7.8.2-1.

Table 7.8.2-1 Sensitivity Analysis

(EIRR %)

	Case \ EIRR	Case (A) EIRR	Case (B) EIRR	Case (C) EIRR
a	Base case	42.62	24.09	36.08
b	10% reduction in diverted traffic	39.71	22.51	33.03
c	20% reduction in diverted traffic	36.64	20.70	29.85
d	50% reduction in diverted traffic	26.17	14.37	19.48
e	10% cost overrun	40.75	22.92	34.01
f	b + e	37.92	21.38	31.08
g	2 years extension of the construction period	49.01	23.99	40.42
h	50% reduction in passengers' time value	40.67	21.13	33.14
i	b + e + h	36.19	18.65	28.34

7-9 Evaluation

The results of the EIRR computation are already set forth in Section 7-8-1. In any of the 3 cases, the opportunity cost of capital in India (estimated to be about 12% in this study) are surpassed substantially, so their effects on the national economy are great.

The EIRR of Case (B) is at relatively a low level. However, if the project for the construction of the New High-Speed Corridor is evaluated in combination with the project for upgrading of the existing Section (Case (C)), the EIRR is 19.48% even diverted traffic volume delines by 50%.

Even in the most pessimistic case of (d) in the sensitivity analysis, the EIRR of Case (B) is 14.37%.

In the case of 2-year extension of the construction period, the EIRR increases in Case (A).

In case (B), EIRR is at almost the same level.

This means that, in Case (A), due to comparatively small diverted traffic volume within 2 years after completion of upgrading the Section, the positive effect of the 2-years investment extension will surpass the decrement in benefits.

The implementation of this project is expected to bring about the secondary effects mentioned below.

(1) Improvement of road traffic conditions

An extensive diversion of traffic from road to railway will take place as a result of implementing this project. As a consequence, there will be a reduction in road accidents and mitigation of the deteriorating air pollution caused by exhaust fumes from automobiles in the urban areas.

(2) Promotion of related industries

Related local industries will be stimulated and expanded by manufacturing of materials and goods for the project. Furthermore, new industries would be created along with the new demand sectors.

(3) Promotion of employment opportunity

Implementation of this project will lead to increased employment of not only construction workers but also staff members of the Indian Railways. It will also result in a general increase in employment by virtue of expanded production activities of related industries.

(4) Technology transfer

New technologies, new equipment, and new facilities will be introduced with this project, and they will result in the technical upgrading of the technological level. As a consequence, the project is expected to become a driving force for the future economic development of the nation.

(5) Development of regional cities

As a result of improved transportation service by railway, regional development will be accelerated towards dissolution of existing gap between Delhi Union Territory and related regional cities.

CHAPTER 8 FINANCIAL ANALYSIS

CHAPTER 8 FINANCIAL ANALYSIS

8-1 Cases for Analysis and Analysis Period

Same as for the economic analysis

8-2 Objective

The objective of financial analysis is to analyze and evaluate the profitability of the project and the cash flow after implementation of the project.

8-3 Method of Financial Analysis

The main purpose of the financial analysis is to forecast income and expenditure and also cash flow. The method of calculating the FIRR, however, is similar to the economic analysis in that it seeks to obtain a discount rate at which the sum of discounted cash flows becomes zero. It is expressed by the following equation:

$$0 = \sum_{i=1}^{n} Ai/(1 + FIRR)^{i-1}$$

where: n: Project life
Ai: Cash flow

Here, the cash flow is the operating profit (operating income minus operating expenditure) plus the depreciation cost (which does not include cash outflow) minus investment costs. Interest has not yet been paid. Therefore, the FIRR can be used as an indicator of the capacity to pay interest on loans or dividends for capital investments. In calculating the FIRR of this project, the residual value of investment is added to the cash flow of the final year of the project life.

As is clear from the above cash flow formula, the cash flow or the FIRR is not influenced by the loan repayment conditions or the level of interest. It is the net cash flow that those repayment conditions or the interest level has influence upon.

Net cash flow is obtained by adding the financed funds to the cash flow and then subtracting the loan repayment and interest payment. Here, the financed funds is equal to the investment costs. The net cash flow is, therefore, obtained by the following equation:

Net cash flow = Operating profit + Depreciation - (Loan repayment + Interest payment)

Note: In this study, the financed funds is equal to the investment costs during the period of upgrading or construction.

8-4 Premises

8-4-1 Price

The prices of the materials, equipment, commodities, and manpower to be used in this project are as follows:

(1) When locally procured

Market price is adopted.

(2) When imported

CIF price plus customs duty, auxiliary duty, and countervailing duty.

Since different tax rates are applied to different kinds of goods, the tax rate is calculated with the weighted average as follows.

Case (A)	126%
Case (B)	115%

8-4-2 Others

As for the analysis period, exchange rate, reinvestment, residual value, inflation, and diversion of electric locomotives and coaches, the premises are the same as in the economic analysis.

8-5 Investment

Market price is adopted for all investment as mentioned in 8-4-1.

Tables 8.5-1∿3 show a breakdown of investment classified by type of construction, kind of currency and the period.

Table 8.5-1 Financial Prices of Investment Costs

(Unit: Million Rs)

Case (A)

Classification	Currency	1988-1990	1991-2007	2008-2024	Total
Electrification	Foreign	33	0	33	66
	Local	119	0	44	163
Signal and telecommunication	Foreign	266	2	163	431
	Local	935	184	559	1,678
Track and structure	Foreign	0	0	0	0
	Local	390	0	20	410
Land aquisition	Foreign	0	0	0	0
	Local	4	0	0	4
Rolling stock	Foreign	0	0	0	0
	Local	1,011	2,612	2,100	5,723
Total	Foreign	299	2	196	497
	Local	2,459	2,796	2,723	7,978
Grand total		2,758	2,798	2,919	8,475

(Note) Reinvestment amounts of respective items are included while residual values are excluded.
Import taxes are included in the local currency portion.

Table 8.5-2 Financial Prices of Investment Costs

(Unit: Million Rs)

Case (B)

Classification	Currency	1995-1999	2000-2012	2013-2024	Total
Electrification	Foreign	199	0	199	398
	Local	2,045	0	689	2,734
Signal telecommunication	Foreign	1,311	544	988	2,843
	Local	2,955	1,260	2,047	6,262
Track and structure	Foreign	0	0	0	0
	Local	8,878	0	0	8,878
Land aquisition	Foreign	0	0	0	0
	Local	537	0	0	537
Rolling stock	Foreign	1,251	0	1,251	2,502
	Local	5,212	2,052	5,927	13,191
Total	Foreign	2,761	544	2,438	5,743
	Local	19,627	3,312	8,663	31,602
Grand total		22,388	3,856	11,101	37,345

(Note) Reinvestment amounts of respective items are included while residual values are excluded.

Table 8.5-3 Financial Prices of Investment Costs

(Unit: Million Rs)

Case (C)

Classification	Currency	1988-1999	2000-2012	2013-2024	Total
Electrification	Foreign	232	33	199	464
	Local	2,164	44	689	2,897
Signal	Foreign	1,577	707	990	3,274
telecommunication	Local	3,890	1,819	2,231	7,940
Track and	Foreign	0	0	0	0
structure	Local	9,268	0	20	9,288
Land aquisition	Foreign	0	0	0	0
	Local	541	0	0	541
Rolling stock	Foreign	1,251	0	1,251	2,502
	Local	8,834	3,100	7,564	19,498
Total	Foreign	3,060	740	2,440	6,240
	Local	24,697	4,963	10,504	40,164
Grand total		27,757	5,703	12,944	46,404

(Note) Reinvestment amounts of respective items are included while residual values are excluded.

8-6 Operating Cost

Calculation method of the maintenance, personnel, and electric power costs is the same as in the economic analysis. The straight-line depreciation method is applied.

Personnel cost is as follows.

Table 8.6-1 Average annual wage of the railway employee for each job (including personnel income tax)

(Unit: Rs)

Job	Annual wage
Driver	39,528
Conductor	23,700
Station staff	25,500
Maintenance staff	25,500
Head office staff	28,056

8-7 Operating Revenue

Operating revenue is calculated as follows:

Passenger revenue = Diverted and induced passenger traffic (passenger-km) x Unit fare per passenger-km

Freight revenue = Diverted freight traffic (ton-km) x Unit tariff per ton-km

Table 8.7-1 Passenger fare

(Unit: Rs/passenger-km)

Type of train	Fare
Super Express	0.14
Long Express	0.36
Express Mail	0.11
Local	0.07

Passenger fare is based on the IR statistics adopted between Delhi and Kanpur.

For the Super Express, five different fares are set up as described in Chapter 7 (7-8-1) with the fare above regarded as the base case.

Freight tariff : Rs. 0.215/ton-km

The Freight tariff is based on the IR statistics reported on Annual Report of Accounts 1985 - 86.

The ratio of traffic volume by type of train during the analysis period is based on the traffic demand forecast.

Table 8.7-2 Ratio of traffic volume in the existing line by types of train

(Unit: %)

Case (A)

Type of train	Ratio
Long Express	7
Express Mail	84
Local	9

Case (B)

Type of train	Ratio
Long Express	
Express Mail	88
Local	12

8-8 Fund Raising Plan

Direct fund raising by IR itself is not required because investment by IR is covered by the financial resources of the Government.

In this study, however, some financing plans are included in the analysis of the financial viability of this project. The financing plans and their conditions are shown in Table 8.8-1 and 8.8-2.

Table 8.8-1 Financing plan

Plan \ Currency	Foreign Currency Portion	Local Currency Portion
1.	Government to Government Borrowing	Government Budget
2.	"	Government Budget (50%) Domestic Rupee Borrowing (50%)
3.	Official overseas Borrowing	Government Budget
4.	"	Government Budget (50%) Domestic Rupee Borrowing (50%)

Table 8.8-2 Terms and conditions of each financing source

Sources \ Items	Interest rate (%)	Term (Years)	Grace (Years)	Repayment
Government Budget	8.5	-	-	Unnecessary
Government to Government Borrowing	2.75	30	10	Semi-annual installment
Official Overseas Borrowing	7.75	20	5	"
Domestic Rupees Borrowing	15	10	4	"

8-9 Results of Analysis

8-9-1 Cash flow analysis

The cash flow and net cash flow for each financial plan is as shown in Table 8.9.1-1 ∿ 3.

This table shows the debt repayment amounts and net cash flow for respective fund-raising programs.

Table 8.9.1-1 Summary of Cash Flow Analysis

Case (A)

(Unit: Million Rs)

Plan	Item	1988-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016-2024	Total
1∿4	Operating income	4,473 (4,473)	13,323 (17,796)	17,339 (35,135)	17,339 (52,474)	17,339 (69,813)	31,210 (101,023)	101,023
	Operating expenses	1,957 (1,957)	3,377 (5,334)	3,902 (9,236)	3,902 (13,138)	3,902 (17,040)	7,024 (24,064)	24,064
	Operating profit	2,516 (2,516)	9,946 (12,462)	13,437 (25,899)	13,437 (39,336)	13,437 (52,773)	24,186 (76,959)	76,959
	Depreciation	545 (545)	783 (1,328)	844 (2,172)	844 (3,016)	844 (3,860)	1,519 (5,379)	5,379
	Investment	4,152 (4,152)	1,221 (5,373)	183 (5,556)	3 (5,559)	791 (6,350)	Δ540 (5,810)	5,810
	Cash flow	Δ1,091 (Δ1,091)	9,508 (8,417)	14,098 (22,515)	14,278 (36,793)	13,490 (50,283)	26,245 (76,528)	76,528
	Loan repayment Interest payment	1,214 (1,214)	1,215 (2,429)	1,286 (3,715)	1,275 (4,990)	1,265 (6,255)	2,192 (8,447)	8,447
	Net cash flow	453 (453)	8,293 (8,746)	12,812 (21,558)	13,002 (34,560)	12,224 (46,784)	24,053 (70,837)	70,837
2	Loan repayment Interest payment	1,988 (1,988)	2,316 (4,304)	700 (5,004)	689 (5,693)	679 (6,372)	1,137 (7,509)	7,509
	Net cash flow	Δ321 (Δ321)	7,191 (6,870)	13,398 (20,268)	13,588 (33,856)	12,810 (46,666)	25,108 (71,774)	71,774
3	Loan repayment Interest payment	1,300 (1,300)	1,387 (2,687)	1,344 (4,031)	1,301 (5,332)	1,172 (6,504)	2,109 (8,613)	8,613
	Net cash flow	367 (367)	8,121 (8,488)	12,754 (21,242)	12,976 (34,218)	12,317 (46,535)	24,136 (70,671)	76,671
4	Loan repayment Interest payment	2,074 (2,074)	2,489 (4,563)	758 (5,321)	715 (6,036)	586 (6,622)	1,055 (7,677)	7,677
	Net cash flow	Δ406 (Δ406)	7,018 (6,612)	13,340 (19,952)	13,562 (33,514)	12,903 (46,417)	25,190 (71,607)	71,607

Note: Figures in parentheses are accumulated amounts.
Figures with Δ means deficit value.

Table 8.9.1-2 Summary of Cash Flow Analysis

Case (B)

(Unit: Million Rs)

Plan	Item	1995-1999	2000-2004	2005-2009	2010-2014	2015-2019	2020-2024	Total
1~4	Operating income	0 (0)	18,902 (18,902)	23,679 (42,581)	25,803 (68,384)	25,803 (94,187)	25,803 (119,990)	119,990
	Operating expenses	0 (0)	9,872 (9,872)	10,943 (20,815)	11,523 (32,338)	11,523 (43,861)	11,523 (55,384)	55,384
	Operating profit	0 (0)	9,030 (9,030)	12,736 (21,766)	14,280 (36,046)	14,280 (50,326)	14,280 (64,606)	64,606
	Depreciation	0 (0)	3,918 (3,918)	4,171 (8,089)	4,277 (12,366)	4,277 (16,643)	4,277 (20,920)	20,920
	Investment	22,389 (22,389)	963 (23,352)	2,893 (26,245)	0 (26,245)	1,804 (28,049)	Δ3,766 (24,283)	24,283
	Cash flow	Δ22,389 (Δ22,389)	11,985 (Δ10,404)	14,014 (3,610)	18,557 (22,167)	16,753 (38,920)	22,323 (61,243)	61,243
1	Loan repayment Interest payment	0 (0)	10,844 (10,844)	10,844 (21,688)	11,525 (33,213)	11,424 (44,637)	11,323 (55,960)	55,960
	Net cash flow	0 (0)	1,141 (1,141)	3,170 (4,311)	7,032 (11,343)	5,329 (16,672)	11,000 (27,672)	27,672
2	Loan repayment Interest payment	0 (0)	18,920 (18,920)	22,128 (41,048)	6,306 (47,354)	6,205 (53,559)	6,103 (59,662)	59,662
	Net cash flow	0 (0)	Δ6,935 (Δ6,935)	Δ8,114 (Δ15,049)	12,251 (Δ2,798)	10,548 (7,750)	16,220 (23,970)	23,970
3	Loan repayment Interest payment	0 (0)	11,732 (11,732)	12,608 (24,340)	12,176 (36,516)	11,745 (48,261)	10,438 (58,699)	58,699
	Net cash flow	0 (0)	253 (253)	1,406 (1,659)	6,381 (8,040)	5,008 (13,048)	11,885 (24,933)	24,933
4	Loan repayment Interest payment	0 (0)	19,808 (19,808)	23,892 (43,700)	6,957 (50,657)	6,526 (57,183)	5,219 (62,402)	62,402
	Net cash flow	0 (0)	Δ7,823 (Δ7,823)	Δ9,878 (Δ17,701)	11,600 (Δ6,101)	10,227 (4,126)	17,104 (21,230)	21,230

Note: Figures in parentheses are accumulated amounts.
Figures with Δ means deficit value.

Table 8.9.1-3 Summary of Cash Flow Analysis

Case (C)

(Unit: Million Rs)

Plan	Item	1988-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016-2024	Total
1∿4	Operating income	4,473 (4,473)	15,834 (20,307)	36,490 (56,797)	48,620 (105,417)	53,067 (158,484)	95,521 (254,005)	254,005
	Operating expenses	1,957 (1,957)	5,028 (6,985)	13,475 (20,460)	15,520 (35,980)	16,250 (52,230)	29,250 (81,480)	81,480
	Operating profit	2,516 (2,516)	10,806 (13,322)	23,015 (36,337)	33,100 (69,437)	36,817 (106,254)	66,271 (172,525)	172,525
	Depreciation	545 (545)	1,521 (2,066)	4,765 (6,831)	5,163 (11,994)	5,266 (17,260)	9,479 (26,739)	26,739
	Investment	5,847 (5,847)	21,477 (27,324)	2,073 (29,397)	3,455 (32,852)	791 (33,643)	Δ3,108 (30,535)	30,535
	Cash flow	Δ2,786 (Δ2,786)	Δ9,150 (Δ11,936)	25,707 (13,771)	34,808 (48,579)	41,292 (89,871)	78,858 (168,729)	168,729
1	Loan repayment Interest payment	1,214 (1,214)	3,383 (4,597)	12,130 (16,727)	12,263 (28,990)	12,770 (41,760)	22,645 (64,405)	64,405
	Net cash flow	453 (453)	8,160 (8,613)	13,577 (22,190)	22,545 (44,735)	28,522 (73,257)	56,213 (129,470)	129,470
2	Loan repayment Interest payment	1,988 (1,988)	5,662 (7,650)	21,440 (29,090)	18,921 (48,011)	6,965 (54,976)	12,196 (67,172)	67,172
	Net cash flow	Δ321 (Δ321)	5,881 (5,560)	4,266 (9,826)	15,887 (25,713)	34,327 (60,040)	66,662 (126,702)	126,702
3	Loan repayment Interest payment	1,300 (1,300)	3,733 (5,033)	13,286 (18,319)	13,823 (32,142)	13,262 (45,404)	21,909 (67,313)	67,313
	Net cash flow	367 (367)	7,811 (8,178)	12,421 (20,599)	20,985 (41,584)	28,030 (69,614)	56,949 (126,563)	126,563
4	Loan repayment Interest payment	2,074 (2,074)	6,012 (8,086)	22,596 (30,682)	20,480 (51,162)	7,457 (58,619)	11,460 (70,079)	70,079
	Net cash flow	Δ406 (Δ406)	5,531 (5,125)	3,110 (8,235)	14,328 (22,563)	33,835 (56,398)	67,398 (123,796)	123,796

Note: Figures in parentheses are accumulated amounts.
Figures with Δ means deficit value.

The net cash flow is of a negative figure at first, but it turns into a black-ink figure due to an increase in the operating profit.

The fiscal years in which the net cashflow for each case and for each financial plan turns into surplus and the accumulated deficit are as shown in Tabe 8.9.1-4.

Table 8.9.1-4 Year when net cash flow turns into surplus and accumulated deficit by the year

(Unit: million rupees)

Plan	Case (A)		Case (B)		Case (C)	
	Year	Required funds	Year	Required runds	Year	Required funds
1	1993	521	2001	62	1993	521
2	1994	753	2010	15,050	1994	753
3	1993	555	2002	335	1993	555
4	1994	804	2010	17,702	1994	804

In both Case (A) and Case (C), net cash flow becomes a positive figure in 1993-1994.

In Case (B), under fund raising programs 2 and 4, a positive net cash flow is yielded in 2010 due to the shortness of the domestic rupee borrowing period and also because of high interest rates. The amount of subsidies or the funds required for additional borrowing is also substantial in this case.

The years in which surplus funds are generated after compensating for accumulated losses, are as shown in Table 8.9.1-5.

Table 8.9.1-5 The year when accumulated net cash flow turns into black figure

Plan	Case (A)	Case (B)	Case (C)
1	1995	2001	1995
2	1996	2016	1996
3	1995	2004	1995
4	1996	2017	1996

In both Case (A) and Case (C), surplus funds are generated in 1995 or 1996.

In Case (B), surplus funds are generated in 2016 and 2017 under plans 2 and 4, respectively. Thus, a relatively long period is required in this case.

8-9-2 FIRR

Based on investment, operating cost and revenue stated above, FIRRs are calculated by computer model and the results are shown in Table 8.9.2-1.

Table 8.9.2-1 FIRR

(%)

Case	Case (A)	Case (B)	Case (C)
FIRR	25.79	9.86	18.00

8-9-3 Sensitivity Analysis

As in the case of economic analysis, sensitivity analysis are conducted and the results are shown in Table 8.9.3-1.

Table 8.9.3-1 Sensitivity Analysis

(FIRR %)

Case	FIRR	Case (A)	Case (B)	Case (C)
		FIRR	FIRR	FIRR
a	Base case	25.79	9.86	18.00
b	10% revenue reduction	23.59	8.34	15.93
c	20% revenue reduction	21.23	6.67	13.74
d	50% revenue reduction	12.61	-	5.99
e	10% cost overrun	24.12	8.71	16.40
f	b + e	22.02	7.23	14.44
g	2 years extension of the construction period	28.79	9.60	19.55

8-10 Evaluation

The FIRR of Case (A) and Case (C) are 25.79% and 18.00%, respectively, in the base case. This indicates the high potential profit of the project.

In Case (B), the FIRR is 9.86%, a level somewhat lower than 10% but higher than the interest rate of 8.5% for government funds. Even if the revenue declines by 50%, which represents the most pessimistic case in the sensitivity analysis, the FIRR of Case (A) is 12.61%. Therefore, the project is still feasible.

The FIRR of Case (B), in which the New High-Speed Corridor is to be constructed, is 9.86% in the base case and less than 8.5% in the event of decrease in revenue. However, if evaluation is made in combination with upgrading the existing line (Case (C)), FIRR becomes 13.74% even if the revenue decreases by 20%.

With regard to cash flow projection, net cash flow will turn positive 2 - 4 years after the start of operations, except under fund-raising programs 2 and 4 in Case (B), and surplus funds are generated 2 - 6 years afterwards. Thus, the period requiring additional loans or subsidies is relatively short.

The conclusion based on an overall judgement of the analytical results is that, as for the base case, any of Case (A), Case (B), or Case (C) are feasible. Profitability is expected to be high especially in the case of upgrading the existing Section.

CHAPTER 9 CONCLUSION AND RECOMMENDATIONS

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9-1 Conclusion

This study on "improving transport capacity and train speed between Delhi and Kanpur" has been conducted in compliance with the general strategy, which was established in the preliminary stage of the study, i.e. to upgrade the existing Delhi-Kanpur Section by 1991, and construct a Delhi-Agra-Kanpur New Corridor by 2000 when railway traffic demand is envisaged to overflow the upgraded transport capacity of the existing Section.

Firstly, taking account of the socio-economic framework of the related area, inter-zonal railway transport demand on the Delhi-Kanpur area was forecasted for 'with upgrading project', 'without upgrading project', and 'with upgrading project and New Corridor Project' cases.

This demand forecast was used as a basis for a technical study to formulate transport plan, rolling stock plan, and upgrading/construction plans for ground facilities.

These plans proved technical feasibility of improvement in transport capacity (approximately 2 times) and train speed (max. 160 km/h) of the existing Ghaziabad-Kanpur Section as well as high-speed train operation (max. 250 km/h) on the New Corridor.

The investment plan based on the technical study was then made for the economic/financial analysis.

The analysis was made on the following three cases:

Case A : With .... Upgrading project
Without .... No Project

Case B : With .... Upgrading project and New Corridor Project
Without .... Upgrading project

Case C : With .... Upgrading project and New Corridor Project
Without .... No project

The result shows that the two projects will greatly contribute to the economic development of India, and that they are also financially viable for the Indian Railway. For example, Case A brings about extremely high EIRR/FIRR figures; i.e. 42.52 and 25.79 respectively. With the assumption that fare level of the Super Express train of the New Corridor is set at a higher level by 25% than that of 2nd class Exp./Mail train of the existing seets in case of B, EIRR and FIRR are 24.09 and 9.86, and in Case C, 36.08 and 18.00 respectively. Moreover, implementation of these projects will bring about various difficult-to-quantify benefits such as mitigation of road traffic accident/atmospheric contamination, promotion of related industries and job opportunity, and development of regional cities.

The immediate implementation of the Upgrading project and subsequent construction of the New Corridor are, therefore, highly recommended.

9-2 Recommendation

Some recommendations are made in the following, to contribute to smooth implementation of the projects and satisfactory operation thereafter.

(1) Harmonious upgrading of the adjacent railway sections

In order to fully utilize the upgraded railway transportation capability on the Delhi (Ghaziabad)-Kanpur section, harmonious upgrading of the adjacent railway sections, i.e. the Kanpur-Howrah section and the railway networks in the Delhi area is inevitable. Especially, immediate improvement of the latter through such measures as track addition, terminal capacity improvement, re-allocation of terminals, separation of passenger and freight traffic and improved traffic information are highly recommended.

(2) Training

To satisfactorily operate/maintain railway systems with heavy traffic density and high train speed as planned in this Study, railway employees must have adequate knowledge, skill and discipline to properly perform their duties. The training plan, outlined in this report, covers only the minimum requirements for acquisition of new technologies. It is, therefore, recommended that the training be executed on an expanded and long-term basis in line with implementation of the project.

(3) Maintenance

In proportion to the increase in traffic density and train speed, needs for the efficient maintenance system, in terms of working time and labour force, will grow. In this report, recommendations and some references on this subject are given. In this context, it is strongly recommended that studies to develop IR's maintenance system toward mechanization and better maintenance control system should be promoted, under a continuing collaboration of experts abroad, taking due consideration to indegenous conditions of India.

(4) Manufacturing technology

This plan is prepared with the policy of the maximum use of domestic product.

In view of introduction of various new technologies, development of high-tech products, in particular, their quality control level is expected.

(5) Further Study on the New Corridor

In this study, technical study for the New Corridor project is conducted in a pre-feasibility level. To promote this project, therefore, implementation of further study is considered necessary.

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