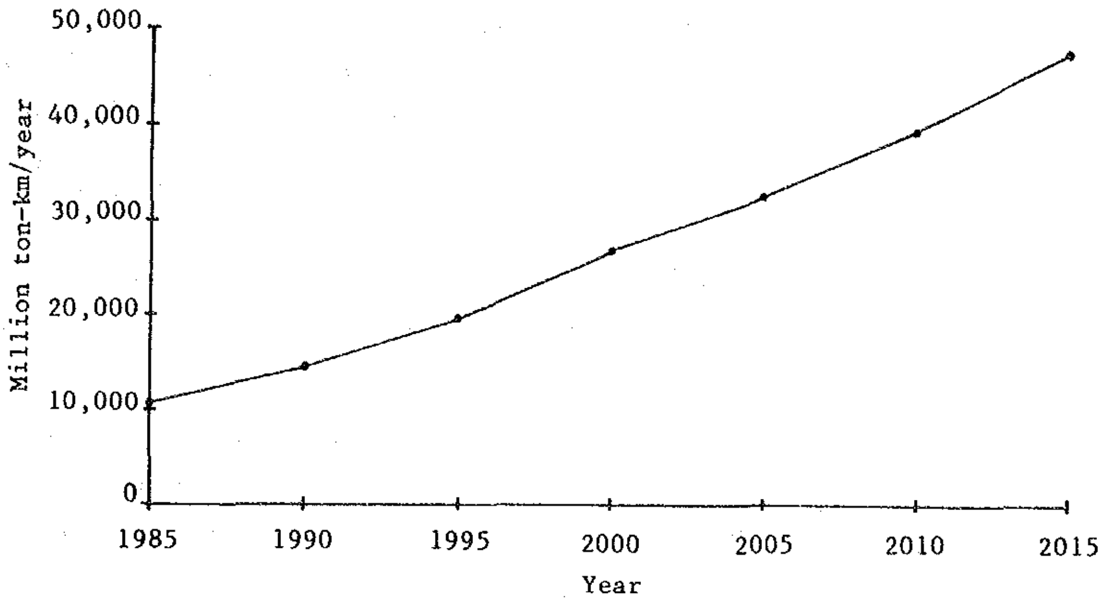


Fig. 3.2.5-11 Future Trend of Traffic Demand for Freight between Delhi and Kanpur

3-2-6 Sensitivity Analysis

Since the forecast of this study covers more than 30 years, the prerequisites may be affected by various factors in the course of such a long period. To cope with such a possibility, sensitivity analysis is made.

(1) In case an expressway is constructed

A case where an expressway is constructed between Delhi and Kanpur (along the same route as the New Corridor) is examined. Given two cases of 25% or 50% fare increase for the New Corridor, assuming 80 km/h or 60 km/h as the expressway service level, and 0% or 25% fare increase for buses, the expected change will be as shown in Table 3.2.6-1. Taking a 25% increase for the New Corridor fare, 80 km/h for the express way service level, and 0% increase for bus fares, the share rate of the New Corridor will be 7.7%. This figure is 58% of the share rate 13.2% which is expected where no expressway is constructed. Likewise, the share rate of the existing line will be 83%, seriously affecting the New Corridor. Taking 60 km/h for the expressway service level, and 0% increase for bus fares, the share rate of the New Corridor will be 9.8%, which is equivalent to 74% of the share rate expectable where no expressway is constructed. The share rate of the existing line will be 90% in this case. Nearly the same result is expectable from the case where a 50% fare increase is applied to the New Corridor.

An expressway, if actually constructed, is expected to extend the time until the traffic demand may reach the limit of the transport capacity.

Nearly the same trend may be expected in freight transport. However, it is expected to be affected less, since the greater part of the freight to be transported by rail is bulky goods as mentioned above.

(2) Change in railway fare structure

In case the railway fare structure of the Section is to be changed as follows:

Condition:
A 25% fare increase be made for both Mail & Express and Long Distance Express.

With higher fare level by 50% or 75% over the current Mail & Express fare be applied to the New Corridor.

Expected changes in the traffic demand are shown in Table 3.2.6-2. The share rate of the all railway lines becomes 57 - 58%, which is 94 - 96% of the share rate before the change in railway fare structure. Although the share rate of the New Corridor increases by 7 - 8%.

Table 3.2.6-1 Sensitivity Analysis on Passenger Traffic Regarding High Way Construction

With New Corridor Construction and Upgrading the Section in 2000

New Corridor: Fare 25% level

Case: Bus speed (km/h)	Case: Fare increase (%)	Rail: Mail & Exp	Rail: Long D/Exp	Rail: New Corridor	Rail: Rail total	Bus	Air line	Total
		24.5%	0.8%	7.7%	32.9%	64.9%	2.2%	100.0%
80	0	345,804	10,989	108,401	465,194	918,056	30,791	1,414,041
		25.7%	0.9%	9.8%	36.4%	60.9%	2.7%	100.0%
60	0	362,897	12,799	138,610	514,306	861,617	38,117	1,414,040
		25.3%	0.9%	9.2%	35.4%	62.0%	2.6%	100.0%
80	25	358,095	12,353	130,646	501,094	876,575	36,371	1,414,040
		26.6%	1.0%	11.2%	38.8%	58.2%	3.0%	100.0%
60	25	376,376	13,801	158,453	548,630	823,573	41,837	1,414,040

With New Corridor Construction and upgrading the Section in 2000

New Corridor: Fare 50% level

Case: Bus speed (km/h)	Case: Fare increase (%)	Rail: Mail & Exp	Rail: Long D/Exp	Rail: New Corridor	Rail: Rail total	Bus	Air line	Total
		24.7%	0.9%	4.8%	30.4%	67.1%	2.5%	100.0%
80	0	349,708	12,426	68,399	430,533	948,363	35,144	1,414,040
		26.3%	1.1%	6.3%	33.7%	63.1%	3.3%	100.0%
60	0	371.283	15,169	89,508	475,960	891,637	46,444	1,414,041
		25.8%	1.0%	5.9%	32.7%	64.2%	3.1%	100.0%
80	25	365,036	14,454	83,600	463,090	907,359	43,591	1,414,040
		27.5%	1.2%	7.5%	36.2%	60.1%	3.7%	100.0%
60	25	389,295	16,866	105,417	511,578	849,592	52,870	1,414,040

(Passenger/day)

Table 3.2.6-2 Sensitivity Analysis on Passenger Traffic Regarding Passenger Fare of the Section

With New Corridor Construction and Upgrading the Section in 2000

Exp./Mail and Long. Exp.: 25% increase

New Corridor fare level %	Mail & Exp	Long D/Exp	New Corridor	Rail total	Bus	Air line	Total
	27.9%	0.9%	10.0%	38.8%	56.9%	4.3%	100.0%
50	394,489	12,955	141,520	548,964	803,962	61,385	1,414,311
	29.1%	1.0%	6.8%	36.9%	57.9%	5.2%	100.0%
75	411,209	14,742	96,095	522,046	819,094	72,899	1,414,039

(Passenger/day)

3-2-7 Planned Traffic Volume

The planned traffic is limited by the track capacity. The track capacity varies depending on various factors such as the number of freight and passenger trains, quality of passenger traffic demand, types of passenger trains, etc. (The track capacity is detailed in the Transport Plan in 4-2 and 5-3).

Planned traffic is calculated considering the traffic demand and the transport capacity of the relevant railway sections. The result of the calculation is shown in Fig. 3.2.7-1 - Fig. 3.2.7-4, and the Table 3.2.7.1.

* Without the project, it is expected that transport capacity will increase commensuraet with traffic demand. After 1991 however, the transport capacity will become a limiting factor and no traffic increase can be expected. The same case applies both to freight and passenger traffic.

* If tne New Corridor is constructed, a large part of the passenger traffic demand will be taken by the New Corridor, but there will still remain passenger traffic and freight traffic demand on the existing Section. On the Delhi - Aligarh section of the Section in particular, where it is expected that only a small part of the traffic will be diverted to the New Corridor, heavy traffic demand will remain.

* On the existing Section, where a larger part of the transport capacity is assigned by freight traffic, the transport capacity for passenger traffic will be heavily restricted.

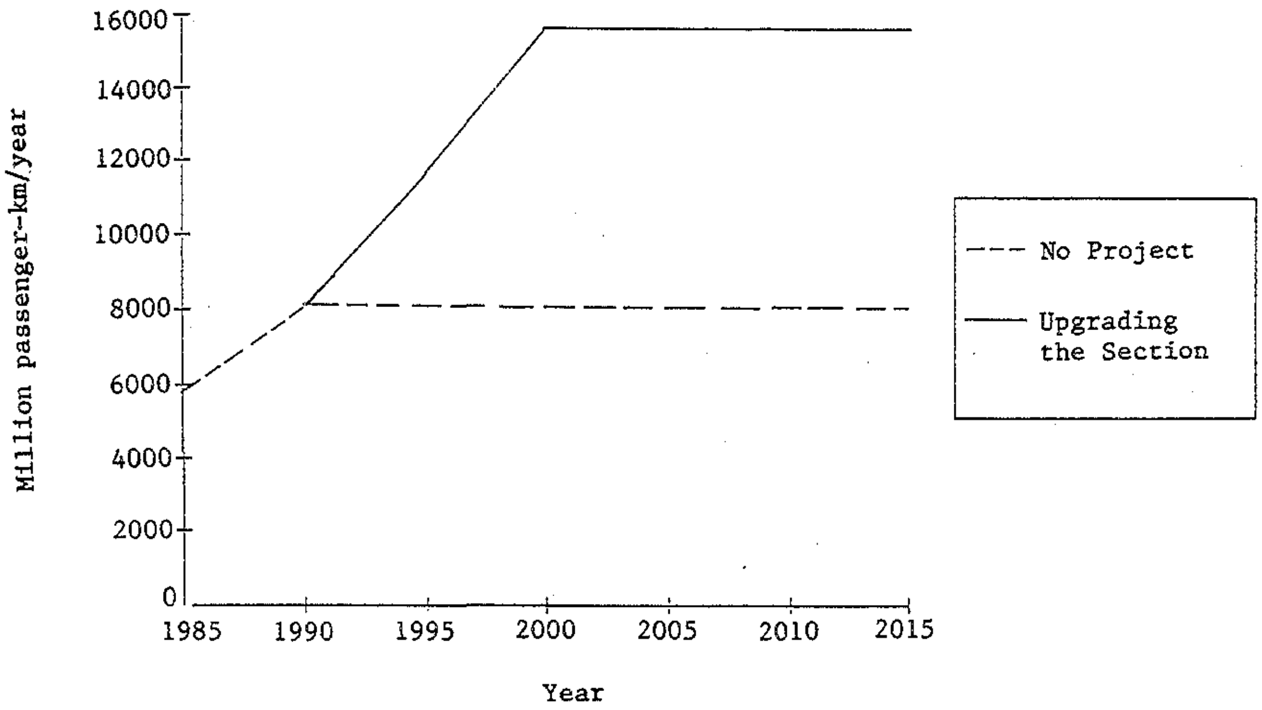


Fig. 3.2.7-1 Planned Passenger Traffic Volume (Section between Ghaziabad and Kanpur)

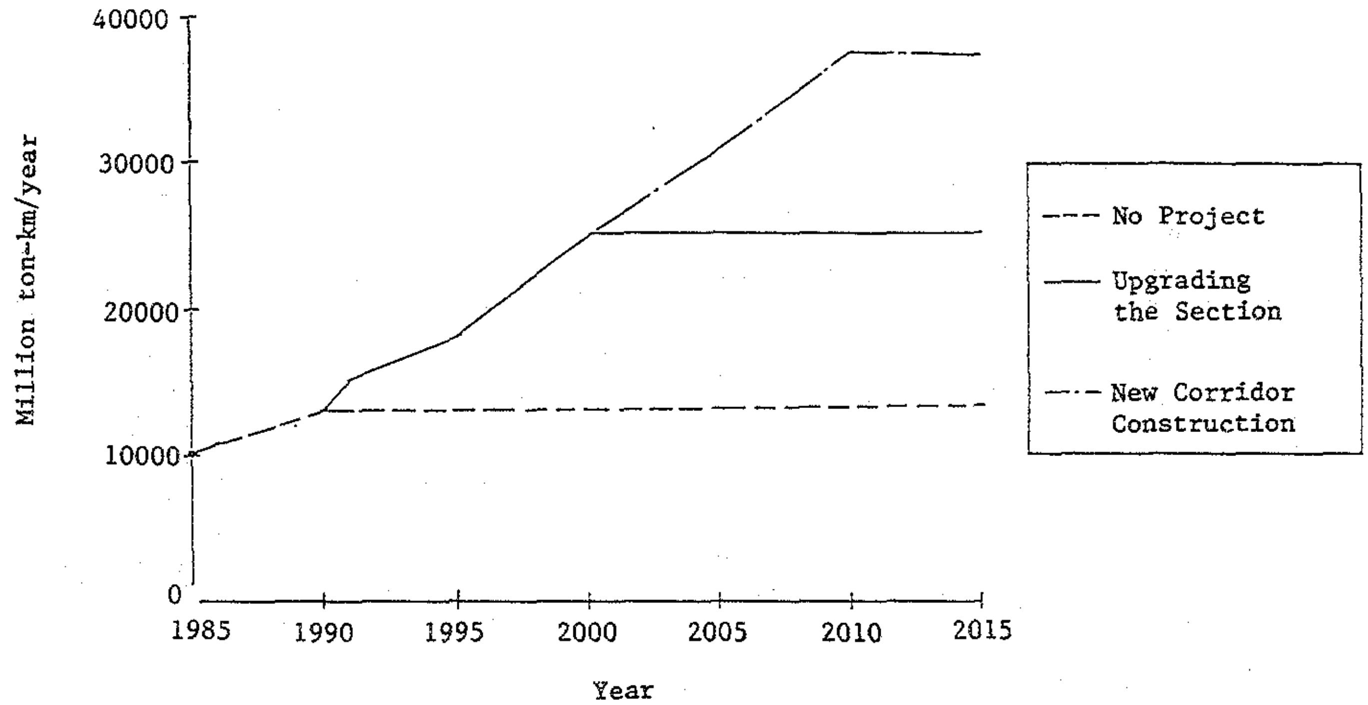


Fig. 3.2.7-2 Planned Freight Traffic Volume (Section between Ghaziabad and Kanpur)

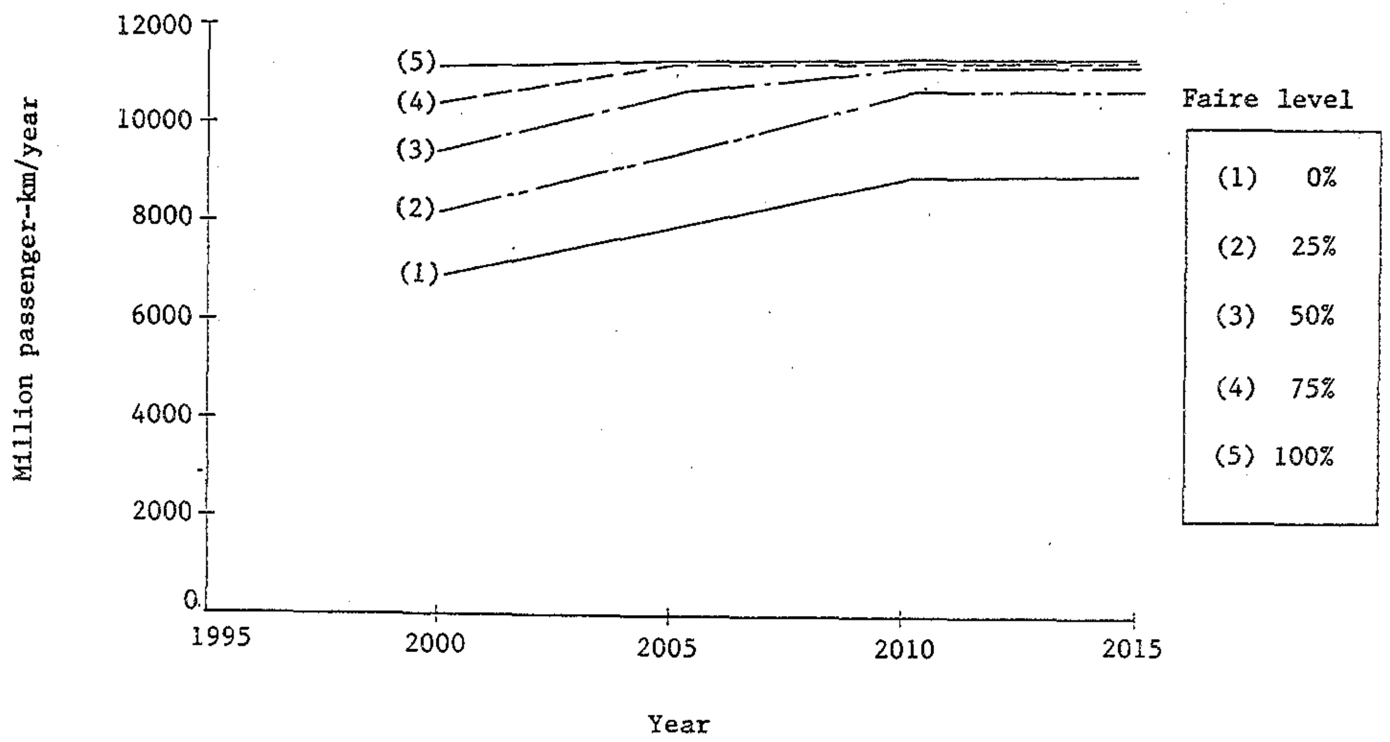


Fig. 3.2.7-3 Planned Passenger Traffic Volume after New Corridor Construction (Section between Ghaziabad and Kanpur)

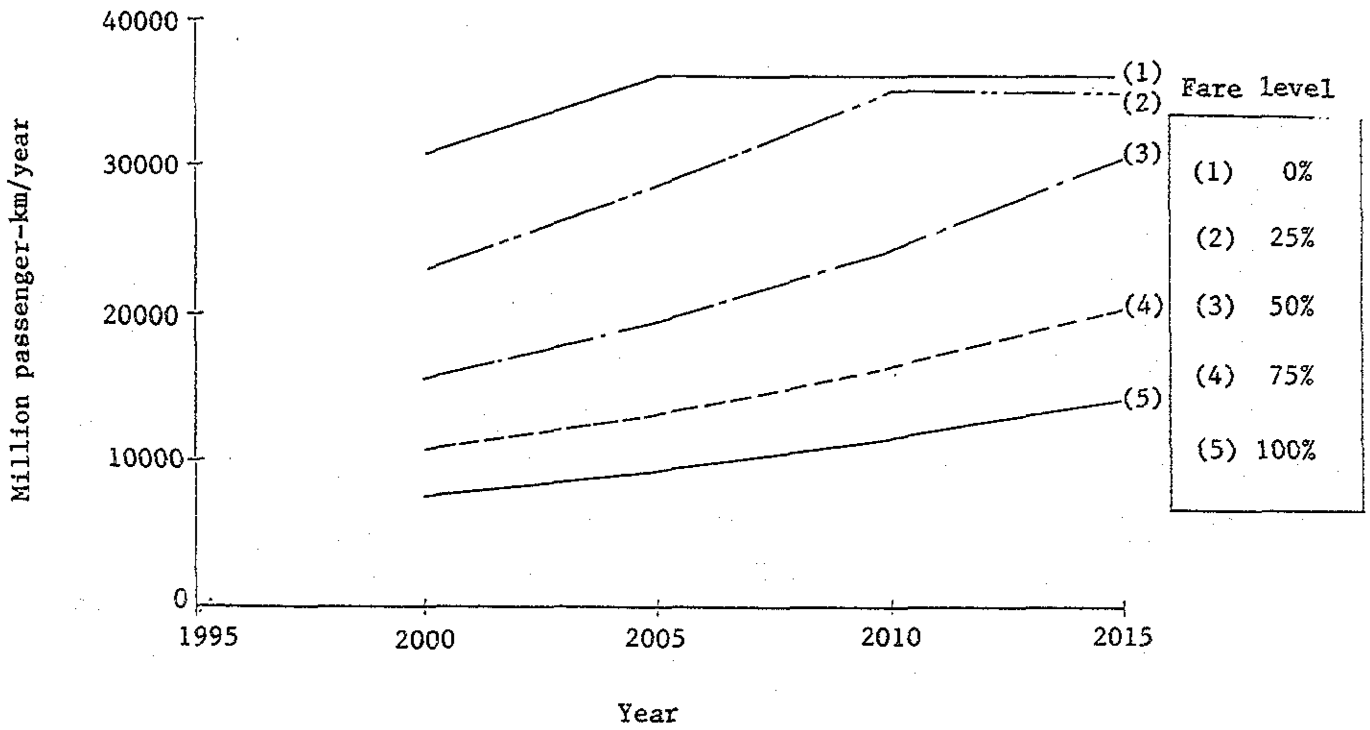


Fig. 3.2.7-4 Planned Passenger Traffic Volume after New Corridor Construction (New Corridor between Delhi and Kanpur)

Table 3.2.7-1 Planned traffic Volume

Planned traffic Volume: Traffic demand Forecasted taking account of actual transport capacity.
Normal Traffic Volume: Traffic volume before implementing the project.

(1) With: Upgrading Section, Without: No project
(Section between Gaziabad - Kanpur)
for Passenger — million passenger-km/year

	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
year	With	Without	With	Without	With	Without			With-Witout	
1985		5,089		5,680						
1990		8,040		8,040		0		8,040		
1991	9,125	8,523	9,125	do	0	482	9,125	8,040	1,085	0
1995	11,482	10,800	11,482	do	0	2,706	11,482	8,040	3,442	0
2000	15,576	14,659	15,576	do	0	6,619	15,576	8,040	7,536	0
2005	18,957	17,840	do	do	3,380	9,799	15,576	8,040	7,536	0
2010	23,070	21,711	do	do	7,494	13,671	15,576	8,040	7,536	0
2015	28,053	20,401	do	do	12,477	18;360	15,576	8,040	7,536	0

for Freight — million ton-km/year

	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
year	With	Without	With	Without	With	Without			With-Witout	
1985		10,158		10,158						
1990		13,735		13,735		0		13,735		
1991	14,641	14,641	14,641	do	0	906	14,641	13,735	906	0
1995	18,541	18,541	18,541	do	0	4,806	18,541	13,735	4,806	0
2000	25,521	25,521	25,521	do	0	11,786	25,521	13,735	11,786	0
2005	31,059	31,059	do	do	5,538	17,324	25,521	13,735	11,786	0
2010	37,707	37,707	do	do	12,276	24,062	25,521	13,735	11,786	0
2015	45,963	45,963	do	do	20,442	32,228	25,521	13,735	11,786	0

(2) With: Upgrading Section and New Corridor Construction, Without: Upgrading Section for Passenger
Case fare level 0%
(Section between Ghaziabad - Kanpur) — million passenger-km/year

	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
year	With	Without	With	Without	With	Without			With-Witout	
2000	6,916	15,576	6,916	15,576	0	0	6,916	15,576	-8,660	0
2005	8,251	18,957	7,912	do	339	3,381	7,912	15,576	-7,664	0
2010	9,843	23,070	8,973	do	870	7,494	8,973	15,576	-6,603	0
2015	11,757	28,053	do	do	2,784	12,477	8,973	15,576	-6,603	0

(New Corridor between Delhi - Kanpur) — million passenger-km/year

	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
year	With	Without	With	Without	With	Without			With-Witout	
2000	30,494	0	30,494	0	0	0	30,494	0	28,744	1,750
2005	38,310	0	35,909	0	2,401	0	35,909	0	35,909	0
2010	48,133	0	do	0	12,224	0	35,909	0	35,909	0
2015	60,752	0	do	0	24,843	0	35,909	0	35,909	0

Case fare level 25%
(Section between Ghazaibad - Kanpur) — million passenger-km/year

	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
year	With	Without	With	Without	With	Without			With-Witout	
2000	8,239	15,576	8,213	15,576	26	0	8,213	15,576	-7,363	0
2005	9,830	18,957	9,386	do	444	3,381	9,386	15,576	-6,190	0
2010	11,727	23,070	10,699	do	1,028	7,494	10,699	15,576	-4,877	0
2015	14,007	28,053	do	do	3,308	12,477	10,699	15,576	-4,877	0

(New Corridor between Delhi - Kanpur) — million passenger-km/year

	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
year	With	Without	With	Without	With	Without			With-Witout	
2000	22,600	0	22,600	0	0	0	22,600	0	21,719	881
2005	28,353	0	28,353	0	0	0	28,353	0	27,247	1,106
2010	35,576	0	34,859	0	717	0	34,859	0	34,859	0
2015	44,842	0	do	0	9,983	0	34,859	0	34,859	0

Case fare level 50%

(Section between Ghaziabad - Kanpur) million passenger-km/year

year	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
	With	Without	With	Without	With	Without			With-Witout	
2000	9,614	15,576	9,458	15,576	156	0	9,458	15,576	-6,118	0
2005	11,470	18,957	10,663	do	807	3,381	10,663	15,576	-4,913	0
2010	13,702	23,070	11,196	do	2,506	7,494	11,196	15,576	-4,380	0
2015	16,344	28,053	do	do	5,148	12,477	11,196	15,576	-4,380	0

(New Corridor between Delhi - Kanpur) million passenger-km/year

year	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
	With	Without	With	Without	With	Without			With-Witout	
2000	15,443	0	15,443	0	0	0	15,443	0	14,931	512
2005	19,427	0	19,427	0	0	0	19,427	0	18,782	645
2010	24,307	0	24,307	0	0	0	24,307	0	23,501	806
2015	30,374	0	30,374	0	0	0	30,374	0	29,366	1,008

Case fare level 75%

(Section between Ghaziabad - Kanpur) million passenger-km/year

year	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
	With	Without	With	Without	With	Without			With-Witout	
2000	10,809	15,576	10,425	15,576	384	0	10,425	15,576	-5,151	0
2005	12,895	18,957	11,270	do	1,625	3,381	11,270	15,576	-4,306	0
2010	15,384	23,070	11,274	do	4,110	7,494	11,274	15,576	-4,302	0
2015	18,375	28,053	do	do	7,101	12,477	11,274	15,576	-4,302	0

(New Corridor between Delhi - Kanpur) million passenger-km/year

year	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
	With	Without	With	Without	With	Without			With-Witout	
2000	10,458	0	10,458	0	0	0	10,458	0	10,261	197
2005	13,028	0	13,028	0	0	0	13,028	0	12,783	245
2010	16,236	0	16,236	0	0	0	16,236	0	15,931	305
2015	20,324	0	20,324	0	0	0	20,324	0	19,942	382

Case fare level 100%

(Section between Ghaziabad - Kanpur) million passenger-km/year

year	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
	With	Without	With	Without	With	Without			With-Witout	
2000	12,109	15,576	11,171	15,576	938	0	11,171	15,576	-4,405	0
2005	14,446	18,957	11,289	do	3,157	3,381	11,289	15,576	-4,287	0
2010	17,235	23,070	do	do	5,946	7,494	11,289	15,576	-4,287	0
2015	20,586	28,053	do	do	9,297	12,477	11,289	15,576	-4,287	0

(New Corridor between Delhi - Kanpur) million passenger-km/year

year	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
	With	Without	With	Without	With	Without			With-Witout	
2000	7,406	0	7,406	0	0	0	7,406	0	7,332	74
2005	9,187	0	9,187	0	0	0	9,187	0	9,095	92
2010	11,403	0	11,403	0	0	0	11,403	0	11,289	114
2015	14,215	0	14,215	0	0	0	14,215	0	14,073	142

for Freight million ton-km/year

year	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
	With	Without	With	Without	With	Without			With-Witout	
2000	25,521	25,521	25,521	25,521	0	0	25,521	25,521	0	0
2005	31,059	31,059	31,059	do	0	5,538	31,059	25,521	5,538	0
2010	37,797	37,797	37,797	do	0	12,276	37,797	25,521	12,276	0
2015	45,963	45,963	do	do	8,166	20,442	37,797	25,521	12,276	0

(3) With: Upgrading Section and New Corridor Construction Without: No project for Passenger

Case fare level 0%

(Section between Ghaziabad--Kanpur) million passenger-km/year

year	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
	With	Without	With	Without	With	Without			With-Witout	
2000	6,916	14,059	6,916	8,040	0	6,019	6,916	8,040	-1,124	0
2005	8,251	17,840	7,912	do	339	9,800	7,912	8,040	-128	0
2010	9,843	21,711	8,973	do	870	13,671	8,973	8,040	933	0
2015	11,757	26,401	do	do	2,784	18,361	8,973	8,040	933	0

(New Corridor between Delhi--Kanpur) million passenger-km/year

year	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
	With	Without	With	Without	With	Without			With-Witout	
2000	30,494	0	30,494	0	0	0	30,494	0	28,744	1,750
2005	38,310	0	35,909	0	2,401	0	35,909	0	35,909	0
2010	48,133	0	do	0	12,224	0	35,909	0	35,909	0
2015	60,752	0	do	0	24,843	0	35,909	0	35,909	0

Case fare level 25%

(Section between Ghaziabad--Kanpur) million passenger-km/year

year	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
	With	Without	With	Without	With	Without			With-Witout	
2000	8,239	14,059	8,213	8,040	26	6,019	8,213	8,040	173	0
2005	9,830	17,840	9,386	do	444	9,800	9,386	8,040	1,346	0
2010	11,727	21,711	10,699	do	1,028	13,671	10,699	8,040	2,659	0
2015	14,007	26,401	do	do	3,308	18,361	10,699	8,040	2,659	0

(New Corridor between Delhi--Kanpur) million passenger-km/year

year	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
	With	Without	With	Without	With	Without			With-Witout	
2000	22,600	0	22,600	0	0	0	22,600	0	21,719	881
2005	28,353	0	28,353	0	0	0	28,353	0	27,247	1,106
2010	35,576	0	34,859	0	717	0	34,859	0	34,859	0
2015	44,842	0	do	0	9,983	0	34,859	0	34,859	0

Case fare level 50%

(Section between Ghaziabad--Kanpur) million passenger-km/year

year	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
	With	Without	With	Without	With	Without			With-Witout	
2000	9,614	14,059	9,458	8,040	156	6,019	9,458	8,040	1,418	0
2005	11,470	17,840	10,663	do	807	9,800	10,663	8,040	2,623	0
2010	13,702	21,711	11,196	do	2,506	13,671	11,196	8,040	3,156	0
2015	16,344	26,401	do	do	5,148	18,361	11,196	8,040	3,156	0

(New Corridor between Delhi--Kanpur) million passenger-km/year

year	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted	Induced
	With	Without	With	Without	With	Without			With-Witout	
2000	15,443	0	15,443	0	0	0	15,443	0	14,931	512
2005	19,427	0	19,427	0	0	0	19,427	0	18,782	645
2010	24,307	0	24,307	0	0	0	24,307	0	23,501	806
2015	30,374	0	30,374	0	0	0	30,374	0	29,366	1,008

Case fare level 75%

(Section between Ghaziabad--Kanpur) million passenger-km/year

year	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted With-Witout	Induced
	With	Without	With	Without	With	Without				
2000	10,800	14,659	10,425	8,040	384	6,610	10,425	8,040	2,385	0
2005	12,895	17,840	11,270	do	1,625	9,800	11,270	8,040	3,230	0
2010	15,384	21,711	11,274	do	4,110	13,671	11,274	8,040	3,234	0
2015	18,375	28,401	do	do	7,101	18,381	11,274	8,040	3,234	0

(New Corridor between Delhi--Kanpur) million passenger-km/year

year	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted With-Witout	Induced
	With	Without	With	Without	With	Without				
2000	10,458	0	10,458	0	0	0	10,458	0	10,261	197
2005	13,028	0	13,028	0	0	0	13,028	0	12,783	245
2010	16,236	0	16,236	0	0	0	16,236	0	15,931	305
2015	20,324	0	20,324	0	0	0	20,324	0	19,942	382

Case fare level 100%

(Section between Ghaziabad--Kanpur) million passenger-km/year

year	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted With-Witout	Induced
	With	Without	With	Without	With	Without				
2000	12,109	14,659	11,171	8,040	938	6,619	11,171	8,040	3,131	0
2005	14,446	17,840	11,289	do	3,157	9,800	11,289	8,040	3,249	0
2010	17,235	21,711	do	do	5,946	13,671	11,289	8,040	3,249	0
2015	20,586	28,401	do	do	9,297	18,361	11,289	8,040	3,249	0

(New Corridor between Delhi--Kanpur) million passenger-km/year

year	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted With-Witout	Induced
	With	Without	With	Without	With	Without				
2000	7,406	0	7,406	0	0	0	7,406	0	7,332	74
2005	9,187	0	9,187	0	0	0	9,187	0	9,095	92
2010	11,403	0	11,403	0	0	0	11,403	0	11,289	114
2015	14,215	0	14,215	0	0	0	14,215	0	14,073	142

for Freight million ton-km/year

year	Traffic Demand						Planned Traffic			
	Total		within Capacity		Over flowed		Total	Normal	Diverted With-Witout	Induced
	With	Without	With	Without	With	Without				
2000	25,521	25,521	25,521	13,735	0	11,786	25,521	13,735	11,786	0
2005	31,059	31,059	31,059	do	0	17,324	31,059	13,735	17,324	0
2010	37,797	37,797	37,797	do	0	24,062	37,797	13,735	24,062	0
2015	45,963	45,963	do	do	8,166	32,228	37,797	13,735	24,062	0

CHAPTER 4 BASIC UPGRADING PLAN FOR THE DELHI–KANPUR SECTION

CHAPTER 4 BASIC UPGRADING PLAN FOR THE DELHI - KANPUR SECTION

4-1 Guidelines of the Study

(1) The Study will put emphasis on minimizing investment costs by making best use of the existing assets, in line with upgrading plans in progress or scheduled.

(2) New technologies will be adopted taking into account coordination with the existing railway system as well as social and natural conditions of India.

(3) The Study on the upgrading the Section will be made with the presumed inauguration year of 1991.

(4) Basic train operation plan will be drawn up based on the traffic demand forecast and upgraded conditions of railway assets on the Section.

1) Train types and their typical capacities/make-ups are as listed below:

Table 4.1-1 Basic Conditions of Transport Plan (The Section)

Train type		Max. speed (km/h)		Average passenger carrying/freight hauling capacity		Average number of coaches/wagons	
		Current	Upgraded	Present	Upgraded	Present	Upgraded
Passenger	L. Exp. (Raj. Exp.)	(120)	160	(880)	1,090	(18)	18
	Exp./Mail	105	130	1,050	1,150	18	19.5
	Local	90	105	761	1,200	10.6	18
Freight	Fast	75	90	4,500 (tons)	4,500 (tons)	56	56
	Ordinary	75	75	2,250 (tons)	2,250 (tons)	28	28

2) The braking distance of the above trains will be less than 2 km.

3) Constituent elements of the train operation plan, such as stopping station, stopping/margin time, maintenance block time, and load factor will be determined conforming to the regulations and existing situations.

4) Travelling time for each type of train will be estimated based on the maximum speed ratio between current and future trains.

5) Track capacity will be estimated taking upgraded train-speed/ground-facilities and assumed train operation pattern as well as 2 hours of maintenance block into account.

6) Number of trains and total train kilometerage after 1990 will be estimated based on the traffic demand forecast, upgraded track capacity and train-carrying capacity.

7) The train operation plan after upgrading the Section will be prepared on the assumption that necessary improvements in transport capacity on the adjacent railway lines will be made in separate projects.

8) The transport capacity in 1990 will be estimated taking account of such upgradings of the Section as increase in hauling capacity, track renewal, additional loops, block huts and power sub-stations which will be implemented in the 7th Five Year Plan.

(5) Rolling stock will be upgraded in accordance with such principles as:

1) To replace Rajdhani Express trains with Long Distance Express (L. Exp.) trains which consist of two ELs and coaches designed to fit high speed operation at 160 km/h.

2) To introduce new types of EL and wagon for haulage of 4500-ton fast freight trains at the maximum speed of 90 km/h.

3) To upgrade the Express/Mail trains to the level of Rajdhani Express, i.e., with air brake, air conditioning and higher train speed (max. 130 km/h).

4) To upgrade the brake system of the local passenger and ordinary freight trains from vacuum to air brake type, taking opportunity of regular replacement of superannuated rolling stock. Consequently, the maximum speed of the local passenger train will be improved to 105 km/h.

(6) Major steps to be taken for the ground facilities to upgrade transport capacity and train speed on the Section are as follows:

1) Track and structure

The following upgrading steps premise that the track renewal work (i.e. 52 kg continuous welded rail, PRC 1540/km sleeper, 30 cm-thick-ballast etc.) will be completed not later than the year of 1990.

a. To improve cant and transition curve of tracks to meet the maximum train speed of 160 km/h.

b. To upgrade turnouts on main tracks to eliminate any speed restriction for run-through trains at 160 km/h and to alleviate the current branch-off speed restriction of 10/15 km/h.

c. To provide new run-through loops separated from platforms or security fences on the platforms to ensure the security of passengers.

d. To improve train handling capacity of the Kanpur station by adding platform(s) and loop(s).

e. To improve turnouts and track layout of the Ghaziabad, Tundla, and Juhi yard to eliminate/alleviate speed restrictions.

f. To improve multiple-span bridges and flyover bridges to enable high-speed train operation at 160 km/h.

2) Signalling and telecommunication

a. To adopt 4 aspect signal system currently used on the Delhi - Ghaziabad Section to maintain uniformity of the signal indication. In addition, speed indicator will be attached to the signals in the station area to indicate speed restriction at turnout.

b. To provide automatic block system of 1 km length to increase track capacity with the brake distance condition of 2 km.

c. To equip level crossings with fixed-time alarming device with train speed check function and motor-drived full barrier.

d. To install solid-state interlocking devices to enhance safety and the efficiency of train handling at stations.

e. To adopt A.F. track circuit which will enable jointless track circuit and thyristor/V.V.V.F car operation.

f. To introduce AWS to secure safety of train operation.

g. To upgrade train dispatcher facilities to improve traffic control capabilities.

3) Electrification

The following upgrading steps premise that the additional 6 sub-stations (12.5 MVA, 2 banks) will be installed not later than the year of 1990.

a. To provide such measures to alleviate railway traffic hindrances caused by frequent tripping of circuit breaker as high-speed automatic circuit reclosing system, reactance-measuring-type fault locator, automatic sequential interrupter closing system, and parallelogram-characteristic static distant relay.

b. To provide necessary modifications to the current OHE equipment to meet train operation at 160 km/h, such as increase in tension of contact/catenary wires and decrease in pre-sag and contact wire gradient.

(7) Upgrading the ground facilities on the Delhi - Ghaziabad section will be excluded from the scope of the Study for the following reasons:

a. Overall traffic demand forecast for the abovementioned section is not available in this Study, for on this section there exists numerous train traffic flows besides the Delhi - Kanpur flow, such as Delhi - Ghaziabad, Delhi - Moradabad, Ghaziabad - Tuglakabad and Delhi - Saharanpur flows, which are irrelevant to the scope of the Study.

4-2 Basic Train Operation Plan

4-2-1 Preconditions of Basic Train Operation Plan

(1) Passenger train

1) Current number of trains by section

Table 4.2.1-1 Status of the Current Train Operation

Train	No. of train	Section (DLI GZB KRJ ALJN TDL SKB ETW CNB)
L. Exp	0	DLI – CNB
Exp. Mail	38	DLI – CNB
Exp. Mail	4	TDL – CNB
Exp. Mail	2	DLI – SKB
Exp. V.P	2	DLI – CNB
Local	2	DLI – TDL
Local	4	DLI – ALJN
Local	2	DLI – KRJ
Local	2	DLI – DKDE
Local	4	ALJN – TDL
Local	2	ALJN – HRS
Local	4	BRN – TDL
Local	4	TDL – CNB
Local	4	TDL – SKB
Local	2	ETW – CNB

Notes: 1. The number of trains (total of Up and Down train) is derived from the Working Time Table dated 1.10.1986.

2. For the section between DL1 and GZB, only number of trains which are operated to/from KRJ through GZB are indicated.

2) Type of trains, running speed, hauling tonnage, type of motive power unit, and type of coach

The maximum speed and the booked speed of Exp/Mail trains will be 130 km/h and 125km/h, respectively.

The maximum speed and the booked speed of local trains will become 105 km/h and 100km/h, respectively.

Table 4.2.1-2 Type of Train, Running Speed, Hauling Tonnage, Type of Motive Power Unit, and Type of Coach

Train	Max. speed (km/h)	Booked speed (km/h)	Hauling tonnage (t)	No. of coaches	E.L	Coaches
Long distance express	160	155	700	18	High-speed E.Lx2	High-speed coach
Exp./ Mail	130	125	1,000 ∿ 1,170	18 21	WAP1	Coaches used for Rajdhani Exp.
Local	105	100	∿ 1,000	4 ∿ 18	WAM4	Existing coach
	100	75		9	-	EMU

3) Number of passengers per train

Table 4.2.1-3 Number of Passengers per Train

Train	Number of passengers (persons)	
	Existing train	New train
L. Exp.	-	*1 1,090
Exp./Mail	Same as the present	*2 1,040 ∿ 1,260
Local	Same as the present	*3 ∿ 1,200

*1: The carring capacity of the L. Exp. train will be larger by approximately 200 passengers compared with the Rajdhani Express (880 passengers).

*2: Considering the average seating capacity (1,040 passengers) of the current 17 Exp/Mail trains, and also the future train formation of 21 coaches, the seating capacity of the new Exp/Mail trains is set at 1,040 - 1,260 passengers.

*3: The seating capacity for local trains shall be the average of that of 5 trains serving between Ghaziabad and Dankaur.

4) Load factor

The load factor for passenger train is assumed to be 100%.

5) Stopping station

The pattern of the present stopping stations shall be kept as it is.

6) Stopping time

a) Long distance express train

The stopping time of L. Exp. train is set at 5 minutes.

b) Other trains

The stopping time is same as they are.

. 15 to 20 min. (at major stations)
. 2 min. (at other stations)
. 10 min. (for water replenishing)

7) Margin time

The margin time ratio is same as they are.

. Between Ghaziabad and Kanpur
Exp./Mail train 34% (DN) * 42% (UP)
(Refer to the Appendix 2-2)

8) Maintenance block

Maintenance block of 2 hours is secured separately for UP and DN trains in the day-time zone.

9) Train-passing speed at stations

a) Tundla (for safety of passengers on the platform): 100 km/h

b) 1,021.6 km ~ Kanpur (speed limit for straight direction at turnout): 120 km/h

c) Other stations: Booked speed

10) Trains covered by the operation plan

Between Delhi and Ghaziabad, the trains operating between Delhi and Ghaziabad, and trains operated beyond Ghaziabad except those which go out to and come in from other lines extending from Ghaziabad are covered.

11) Passenger transport facilities in Delhi area

a) It is supposed that the capacity of the train arrival and departure tracks, and the rolling stock stabling tracks at Delhi and New Delhi Stations are enough for the operation of the additional trains.

b) The track capacity of track between Delhi/New Delhi and Ghaziabad is assumed as sufficient to meet with the operation of additional trains.

12) Change of locomotives for L. Exp.

Locomotives for L. Exp. are to be changed at Delhi and Kanpur Stations.

(2) Freight train

1) Current number of trains with operative section

Table 4.2.1-4 Number of Freight Trains by Section

GZB–KRJ	KRJ–ALJN	ALJN–TDL	TDL–FKD	FKD–SKB	SKB–KNS	KNS–PNK	PNK–CNB (GMC)
39	39	39	35	35	35	35	35
	6	6		3	3	3	3
		3			4	4	4
			2	2	2	2	
			2	2	2		
			2	2			
39	45	48	41	44	46	44	42

Note: 1. The number of trains (both way/day) are derived from the Working Time Table dated 1.10.1986.

2) Type of train, running speed, hauling tonnage, type of motive, power unit, and type of wagon

New, fast freight trains made up of BOXN and BCN will run at the maximum speed of 90 km/h.

Table 4.2.1-5 Type of Train, Running Speed, Hauling Tonnage, Type of Motive Power Unit, and Type of Wagon

Train	Max. speed (k/h)	Booked speed (k/h)	Hauling tonnage (t)	No. of wagons	E.L	Wagons
Fast	90	85	4,500	56	WAG6	BOXN & BCN
Ordinary	75	70	2,250 (3,600)	28 (44)	WAG4 (WAG5)	BOX & BCX

3) Average hauling tonnage per train

According to the DOMESTIC STATISTICS PART-1 Traffic (1986 NORTHERN RAILWAY), the average hauling tonnage per train has increased by 4.6% per annum during the 1981/82 - 1985/86 period.

The average hauling tonnage in 1990/91 is estimated assuming that the same increase rate will be achieved in the 7th 5-year plan by introducing more BOXN.

Table 4.2.1-6 Average Hauling Tonnage by Section

(ton/train)

	GZB – ALJN	ALJN – TDL	TDL – ETW	ETW – CNB
1985 - 86	1,425	1,434	1,594	1,616
1990 - 91 and afterward	1,780	1,790	1,990	2.020

4) Stopping station

The existing trains shall stop at the same stations as they are. The new trains to be introduced shall, in principle, run without stop between major stations.

5) Stopping time

Except for the case which a train is overtaken by other train, the current stopping time is to be kept. (Except at Tundla where the average stopping time is 45 min.)

6) Margin time

The margin time ratio is same as they are.

Table 4.2.1-7 Current Margin Time

(%)

Train	UP	DN
GZB ∿ TDL	54	49
TDL ∿ GMC	39	54

Note: 1. The table shows the cases of non-stop freight train.

7) Freight transport facilities

The freight yard and the freight handling facilities are assumed to have enough capacity for operating the additional trains to be put into operation.

8) Trains covered by train operation plan

The freight trains operating between Ghaziabad and Kanpur are covered.

4-2-2 Basic Operation Plan

(1) Traffic demand

The cross-sectional traffic between major stations is forecasted as follows.

Table 4.2.2-1 Cross-sectional Traffic by Year

	Year	DLI – GZB	GZB – KRJ	KRJ – ALJN	ALJN – TDL	TDL – SKB	SKB – ETW	ETW – CNB
Pass. (man/day)	1991	136,949	74,408	64,337	55,820	56,647	58,971	58,991
	1995	174,942	93,950	80,217	71,071	70,735	73,430	74,297
	2000	241,070	128,054	107,892	97,580	94,360	98,666	100,970
	2005	293,382	155,842	131,305	118,754	114,836	120,016	122,880
	2010	357,045	189,660	159,798	144,524	139,755	146,059	149,545
	2015	434,167	230,625	194,313	175,742	169,942	177,607	181,847
Freight (ton/day)	1991	86,908	85,213		99,322	102,509		104,026
	1995	110,040	107,993		125,945	129,753		131,619
	2000	151,464	148,647		173,358	178,598		181,167
	2005	184,332	180,903		210,977	217,354		220,480
	2010	224,318	220,146		256,743	264,504		268,308
	2015	272,787	267,713		312,218	321,654		326,282

Note: 1. The cross-sectional traffic between DLI and GZB, includes trains which go out from or come in to other lines.

(2) Travelling time and commercial speed

The travelling times of each type of train between Delhi/New Delhi and Kanpur are calculated taking into account the train speed increase between Ghaziabad and Kanpur.

1) Passenger train

a) L. Exp. train

Travelling time and commercial speed of the L. Exp. train is shown in the table 4.2.2-2 comparatively with those of Rajdhani Exp. train.

Table 4.2.2-2 Travelling Time and Commercial Speed of Rajdhani Exp. and L. Exp. Train

Max. speed (k/h)		Travelling time (min.)		Time saved (min.)	Commercial speed (k/h)	
		Rajdhani Exp.	L. Exp.			
Radjdhani Exp.	L. Exp	Average	Average		Rajdhani Exp.	L. Exp
120	160	309	259	50	85	102

b) Exp./Mail train

Estimated travelling time and commercial speed before and after the upgradation is shown in the following table.

Table 4.2.2-3 Travelling Time and Commercial Speed of Exp./Mail Train before and after Upgrading

Max. speed (k/h)		Travelling time (min.)		Time saved (min.)	Commercial speed (k/h)	
		Before	After			
Before	After	Average	Average		Before	After
105	130	408	363	45	64	72
100	130	445	390	55	59	67

c) Local train

The comparatively short inter-station distance reduces the time shortening effect expected from increased speed. (A maximum 25 second time reduction is expectable at the longest station interval of 9 km.)

In the operation plan, therefore, the current train operating time will be employed.

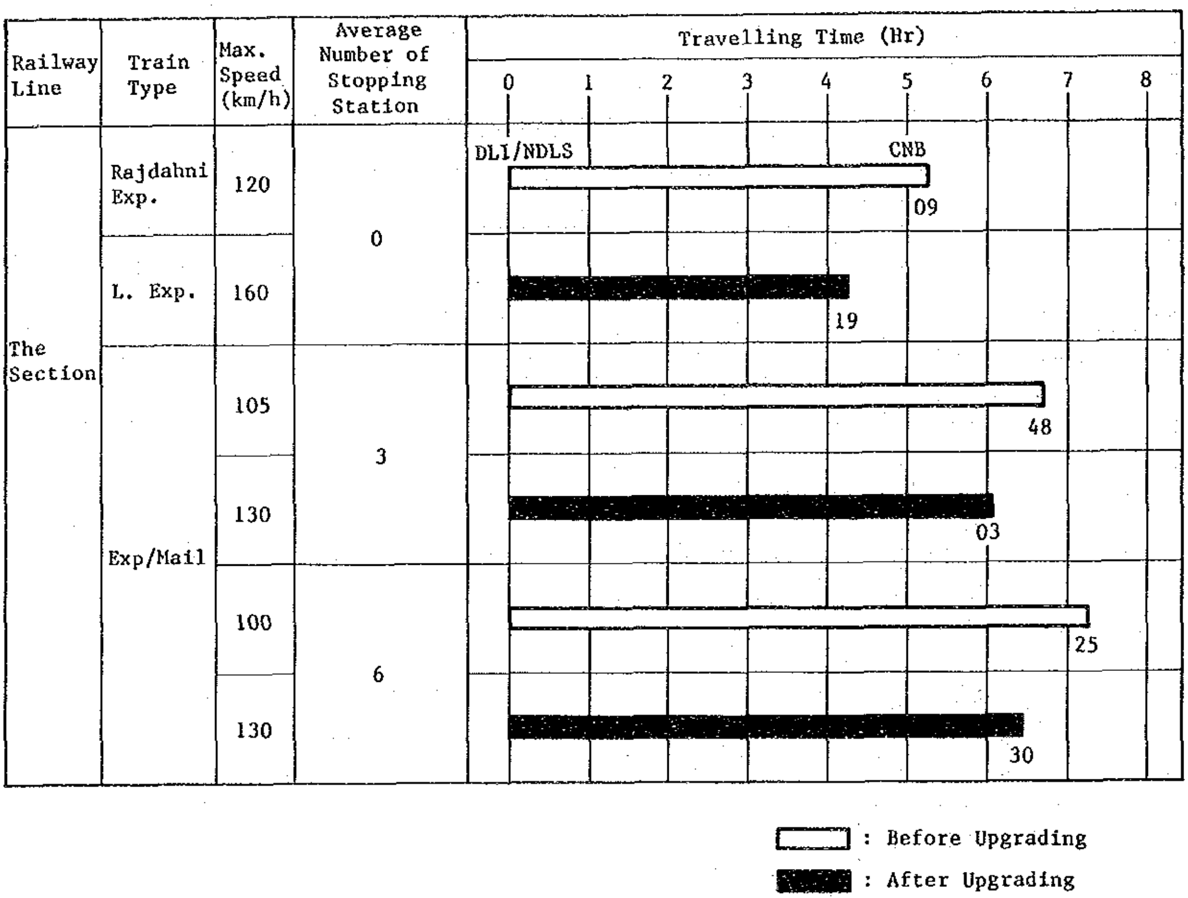


Fig. 4.2.2-1 Travelling Time

2) Freight train

a) Fast train

The travelling time and commercial speed between Ghaziabad and Kanpur of the non-stop fast freight train before and after the upgrading are shown in the Table 4.2.2-4.

Table 4.2.2-4 Average Travelling Time and Commercial Speed between Ghaziabad and Tundla (183.84 km)

Travelling time (min.)		Time saved (min.)	Commercial speed (k/h)	
Before (75 k/h)	After (90 k/h)		Before	After
*1 230	205	25	48	54

Table 4.2.2-5 Average Travelling Time and Commercial Speed between Tundla and Kanpur (227.36 km)

Travelling time (min.)		Time saved (min.)	Commercial speed (k/h)	
Before (75 k/h)	After (90 k/h)		Before	After
*2 253	223	30	54	61

Notes:
1. *1 shows the average travelling time of the following 12 trains, i.e. A43, A41, A39, A1, A13, A11, A27, A29, A31, A33, A35 and A37.
2. *2 shows the average travelling time of the 9 trains i.e. A3, A5, A31, A19, A23, A29, A39, A33 and A47.
3. The travelling time is calculated based on the running time in the Northern Railway Working Time Table dated 1.10.1986.

b) Ordinary train

Travelling time is kept unchanged.

(3) Transport Plan

Fig. 4.2.2-2 shows the number of trains calculated based on the demand forecast results and the aforementioned basic operation plan.

As Fig. 4.2.2-2 shows, the transport capacity is improved in 1991 by upgrading the railway assets, and nevertheless the number of trains is expected to reach the track capacity by the year 2000 in the section between ALJN and TDL.

The number of trains operated in 1990 is estimated considering the improvement plan of the 7th 5-year plan and the past growth of transport capacity on the section.

(Refer to Appendix 2-3)

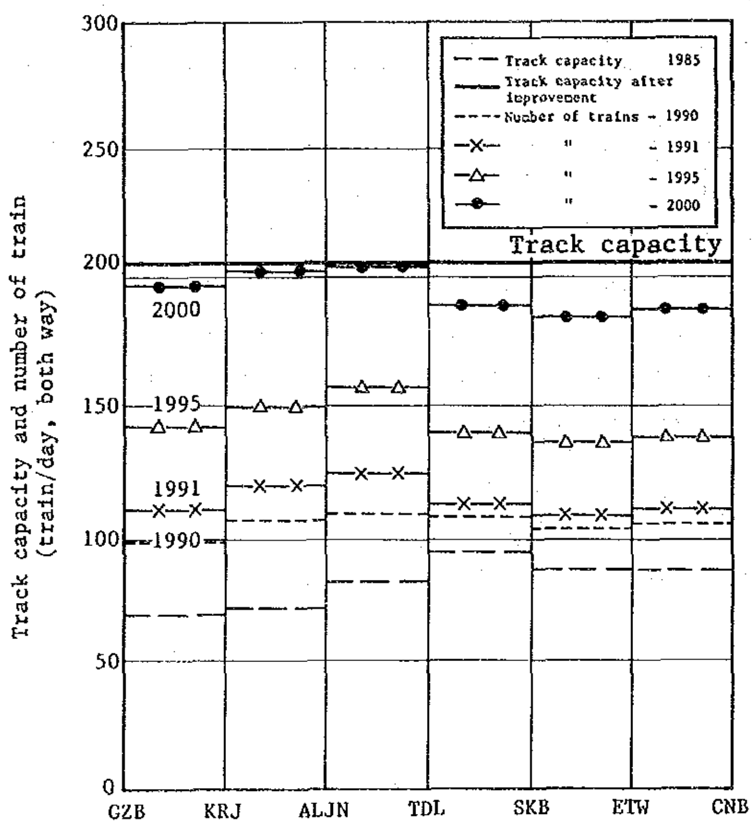


Fig. 5-1 Yearly Number of Trains and Track Capacity of the Section

Table 4.2.2-6 Sectional Train Number by Year

Year	Train	GZB	KRJ	ALJN	TDL	SKB	ETW	CNB
1985	P		52	54	52	54	48	50
	F		39	45	48	44	46	44
	M		1	1	1	2	2	2
	T		92	100	101	100	96	96
1990	P		55	57	55	57	51	53
	F		43	49	54	49	51	51
	M		1	1	1	2	2	2
	T		99	107	110	108	104	106
1991	P		68	70	68	61	55	57
	F		43	49	56	50	52	52
	M		1	1	1	2	2	2
	T		112	120	125	113	109	111
1995	P		87	88	86	74	69	71
	F		55	61	71	64	66	66
	M		1	1	1	2	2	2
	T		143	150	158	140	137	139
2000	P		116	116	107	97	91	93
~	F		78	84	97	88	90	90
	M		2	2	2	4	4	4
2015	T		196	202	206	189	185	187

Notes:

1. The number of trains is the total of up and down trains per day.
2. P, F, M, and T in the column of "Train" mean Passenger, Freight, Miscellaneous Train, and Total (up + down), respectively.
3. For 1990, the number of trains expected after completion of the 7th 5-year plan is indicated.
4. The upgraded track capacity is estimated as much as 206 trains. (Refer to Appendix 2-5).
5. For the kind of trains, refer to Appendix 2-6.
6. The hatched number shows the train number equivalent to the track capacity.

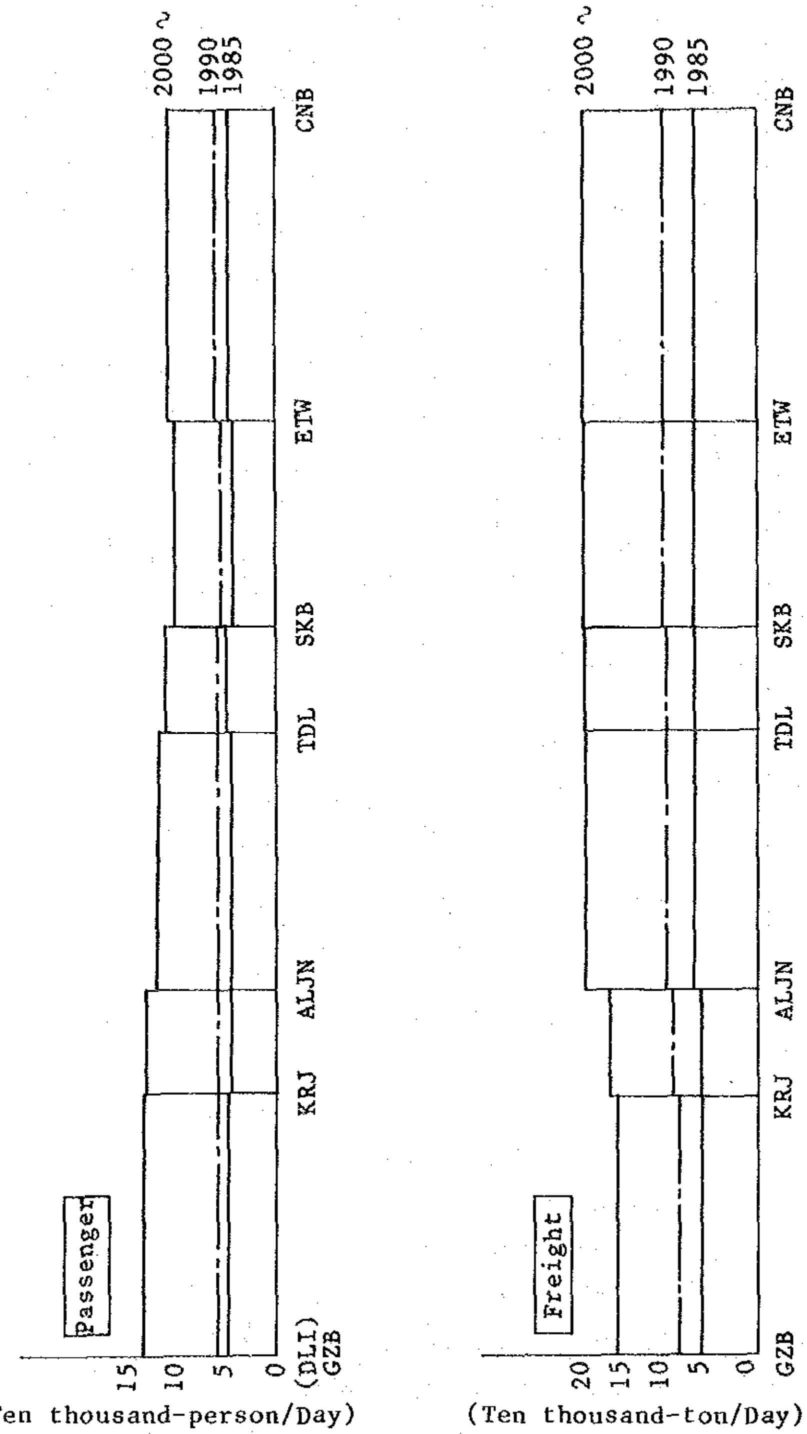


Fig. 4.2.2-3 <u>Cross-sectional Traffic of the Section</u>

4-3 Rolling Stock

4-3-1 Fundamental Concept

The fundamental concept of the upgradation of the rolling stock is described below.

- For high speed trains, new type of rolling stock provided with new technologies shall be introduced and domestically manufactured.
- For rolling stock of other trains, gradual upgrading, including replacement of vacuum brakes with air brakes, shall be made taking opportunity of regular replacement of superannuated rolling stock and/or introduction of additional ones.
- In the aforementioned upgrading, minimization of the investment cost and standardization of the rolling stock shall be taken into consideration.

4-3-2 Basic Performance

(1) Track conditions

1) Grade : less than 5/1,000
2) Sharpest curve: 1,000 radius

(2) Operating condition

1) Max. speed and hauling tonnage

Long distance (L.) Express train:	160 km/h,	700 t (18 coaches)
Exp./Mail passenger train:	130 km/h,	1,000 t (18∿21 coaches)
Local passenger train :	105 km/h,	1,000 t (18 coaches)
Fast freight train :	90 km/h,	4,500 t (56 wagons)
Ordinary freight train :	75 km/h,	2,250 t (28 wagons)

2) The braking distance shall be less than 2 km for all trains.

3) All trains shall be hauled with EL.

L. Express trains shall be hauled with two (2) ELs. (The EMU-commuter-operation section will be extended beyond Ghaziabad up to Aligarh.)

4) Comparison between EL traction System and EMU System for L. Exp. train

a) A comparison of the EL system and the EMU system in procurement cost and maintenance cost per passenger indicates that the EL system is more advantageous in all respects as shown below:

Ratio between EL and EMU:
Procurement cost = 79 : 100
Maintenance cost = 91 : 100

b) EL will become more advantageous if the following facts were taken into consideration:

- Double EL and single EL tractions are expected to be applied for the Delhi - Kanpur section (160 km/h) and Kanpur-Calcutta section (110 km/h) respectively, while if the EMU were used on the above sections, it must be operated throughout the entire Delhi-Kanpur section, thus requiring a large number of EMU unit.

- Adoption of the EMU system can reduce the axle weight of L. Exp. trains. However, since the other trains operated in the Section are of EL traction, remarkable track maintenance cost reduction cannot be expected.

c) For the aforementioned reasons, it is reasonable to employ EL traction system for the L. Exp. trains.

(3) Basic performance

Particulars and basic performance of each train of the aforementioned conditions are shown in Table 4.3.2-1.

Table 4.3.2-1 Particulars of Trains on the Section (Tentative plan)

Condition:
- Straight line
- Level
- Speed meter error: 2%
- Distance margin : 10%

	Passenger train			Freight train	
	L. Express (4,500 kW / 3,500 kW)	Express/Mail	Local	Fast	Ordinary
Type of EL	New EL x 2	WAP1	WAM4	WAG6 (WAG5)	WAG4 (WAG5)
EL weight (ton)	123 x 2 / 78 x 2	108.3	112.8	123 (118.8)	87.6 (118.8)
Brake system (train)	Air	Air	Vacuum	Air	Vacuum
Coaches/Wagons	Light-coaches	Existing coaches	Existing coaches	BOXN BCN	BOX BCX
Carrying capacity (passengers)	1,090	1,040 ∿ 1,260	1,200	-	-
Hauling tonnage (ton)	700	1,000 ∿ 1,170	1,000	4,500 (2,250)	2,250 (3,300)
No. of coaches/ wagons	18	18 ∿ 21	18	56 (28)	28 (40)
Train length (m)	470	421 ∿ 488	422	621 (320)	402 (566)
Max. speed (km/h)	160	130	105	90	75
Acceleration (m/s^2) (at 5 km/h)	0.54 / 0.33	0.13	0.19	0.06	0.08
Deceleration (m/s^2)	0.53	0.38	0.30	0.16	0.13
Braking distance (m) full service	1,936	1,813	1,462	1,982	1,802
Axle weight (ton)	20.5 / 19.5	18.05	18.8	20.5 (19.8)	21.9 (19.8)

(4) Control system

1) Power control

The new type ELs to be used for L. Express trains and fast freight trains, will be equipped with thyristor notchless voltage control system and/or 3-phase asynchronous motor, to improve the acceleration curve.

Conventional ELs used for other trains shall be of the current tap changing control.

2) Brake control

As shown in Table 4.3.2-2, the L. Express trains will be equipped with electromagnetic air brake with disc brake systems in addition to regenerative brake and/or the current rheostatic automatic air brakes, to secure 2 km braking distance.

Other trains shall use the current brake system for the time being, but improvement will be made in the future as indicated in Table 4.3.2-2.

Table 4.3.2-2 Application of Brake Control

Type of brakes	Passenger trains				Freight trains	
	L. Express		Express/ Mail	Local	Fast	Ordinary
	Bo-Bo-Bo	Bo-Bo				
Regenerative brake	-	●	-	-	-	-
Rheostatic brake	○	-			○	○
Electromagnetic air brake	●	●	-	-	-	-
Automatic air brake	○	○	○	(○)	○	(○)
Vacuum brake	-	-	-	○	-	○
Disc	●	●	-	-	-	-
Brake shoe	-	-	○	○	○	○

Notes: ○: Current system ●: New system
(○): To be introduced in future

4-3-3 Principal Specifications and Characteristics

(1) Principal specifications

The particulars of each EL, coach and wagon are given in Table 4.3.3-1, 4.3.3-2.

(2) Characteristics

The balancing speed of each train is much higher than the max. speed. The acceleration characteristic is also considered to be good enough for practical use.

The braking distance is within 2 km for all trains.

The characteristics of the trains are as shown in the Appendix.

1) Speed vs. tractive effort and train resistance curves: (Appendix 3-1)
2) Acceleration curve : (Appendix 3-2)
3) Deceleration curve : (Appendix 3-3)

Table 4.3.3-1 Particulars of EL on the Section

Item \ Kind		Passenger				Freight	
Type of train		L. Express		Express/Mail	Local	Fast	Ordinary
Type of EL		New EL		WAP1	WAM4	WAG6 (WAG5)	WAG4 (WAG5)
Axle arrangement		Bo-Bo-Bo	Bo-Bo	Co-Co	Co-Co	Co-Co	B-B (Co-Co)
Tare (ton)		123	78	108.3	112.8	123 (118.8)	87.6 (118.8)
Axle weight (ton)		20.5	19.5	18.05	18.8	20.5 (19.8)	21.9 (19.8)
Max. length (mm)		20,922	20,000	18,794	19,974	20,922 (19,974)	17,216 (19.974)
Rated power (kW)		4,560	3,500	2,795	2,677	4,560 (2,832)	2,324 (2,832)
Max. speed (km/h)		160		130	105	90	75
Gear ratio		2.43	4.8	2.76	4.13	3.94 (4.13)	3.95 (4.13)
Control system		Thyristor phase control	3-phase control	High voltage tap changer	High voltage tap changer	Thyristor Phase control (High voltage tap changer)	High voltage tap changer
Brake system	EL	Rheostatic . Air	Regenerative.Air	Air	Rheostatic . Air	Rheostatic . Air	Rheostatic . Air
	train	Electromagnetic . Air		Air . Vacuum	Vacuum	Air . (Air. vacuum)	Vacuum . (Air.vacuum)
Bogie system		Z-type link Barrel rubber		Equalizer beam	Equalizer beam	Low center plate Equalizer beam (Equalizer beam)	Equalizer beam
Suspension of traction motor		Bogie mounted		Nose suspension	Nose suspension	Nose suspension	Bogie mounted (Nose suspension)
Traction motor power (kW)		760 x 6	875 x 4	566 x 6	566 x 6	760 x 6 (566 x 6)	1,146 x 2 (566 x 6)
Transformer capacity (kVA)		Primary 6,000 Seco. 5,700 Tert. 900		Primary 3,900 Seco. 3,900 Tert. 180,250	Primary 3,460 Seco. 3,460 Tert. 180	Primary 5,992 (3,900) Seco. 5,692 (3,900) Tert. 120,180 (180,250)	Primary 3,460 (3,900) Seco. 3,460 (3,900) Tert. 180 (180,250)
Braking resistor (kW)		2,700	-	-	-	2,700 (-)	-
Compressor (ℓ/min.)		1,500 x 2		1,000 x 3	1,000 x 2	1,500 x 2 (1,000 x 3)	1,000 x 2 (1,000 x 3)
Exhauster (ℓ/min.)		-		4,500 x 2	7,000 4,500	- (4,500 x 2)	1,246 1,869 (4,500 x 2)
Power per weight (kW/ton)		37	44.9	25.8	23.7	37 (23.8)	26.5 (23.8)

Table 4.3.3-2 Particulars of Coaches and Wagons on the Section

Item \ Kind		Coaches			Wagons	
Type of train		L. Express	Express/Mail	Local	Fast	Ordinary
Type of coaches/ Wagons		Light coach	WSCZAC	GS	BOXN	BOX
Carrying capacity (passengers)		75	71	90	-	-
Floor area (m^2)		-	-	-	28.87	35.84
Capacity (m^3)		-	-	-	56.29	62.75
Tare (ton)		33.0	53.3	40.3	22.6	25.0
Carrying weight (ton)		7.5	7.1	9.0	58.7	56.28
Max. axle weight (ton)			16.25			
Max. length (mm)	BUFFER		22,297	22,297	10,713	13,716
	BODY	23,000	21,337	21,337	9,783	12,800
Max. width (mm)		3,245	3,245	3,245	3,200	3,136
Max. height (mm)		4,039	4,039	4,025	3,225	3,155
Bogie system		Bolster - less	Under balance wing spring	Under balance wing spring	Side sill guide coil spring	Lamellar spring
Wheel base (mm)		2,896	2,896	2,896	2,000	2,000
Wheel diameter (mm)		914	914	914	1,000	1,000
Max. speed (km/h)		160	130	75 (105)	90	75
Brake system		Electromagnetic air brake, Air	Air	Vacuum	Air	Vacuum
air condition		Yes	Yes	No	-	-

4-3-4 Upgrading of Rolling Stock

(1) Main features

Main features of rolling stock upgrading for each type of train are shown in Table 4.3.4-1 and Fig. 4.3.4-1.

(2) L. Express Train

- A common use of the EL of the 4,500 kW Bo-Bo-Bo type (WAG6) by changing gear ratio for high-speed passenger trains is considered feasible.

  In the near future, however, employment of a 3-phase asynchronous power system with improved traction characteristics will enable double traction by the 3,500 kW Bo-Bo type.

  In this study, therefore, both traction systems are described. (See Table 4.3.3-1.)

- A making up way of a L. Exp. train is made modifing that of the Rajdhani Express Train. That is, as shown in Fig. 4.3.4-1, to raise the carrying capacity, the power is fed to coaches from EL dispensing with three power-supply cars, and eliminating one pantry car but adding one A/C sleeper instead. (See Table 4.3.2-1.)

1) Electric locomotives (EL)

a) Bogie for high speed train

• Bogie structure

- By adopting the Bo-Bo-Bo or Bo-Bo bogie arrangement through the use of 2-axle bogies, the follow-up characteristics between track and wheels at high-speed running on a curve will be improved, safety enhanced, stress on various parts of the bogie reduced, and occurrence of cracks prevented.

Table 4.3.4-1 Outline of Rolling Stock Upgrading

Type of train / Item	Introduction of new type rolling stock	New acquisition	Upgrading	Remarks
Long distance Express train	• EL and coach (PC) for high-speed. (Train to be hauled with 2 ELs.)	——	——	
Express/Mail passenger train	——	• EL and PC currently used for the Rajdhani Express train. (WAP1 and air brake equipped PC.)	——	
Local passenger train	——	——	• EL (WAM4) currently used for Exp./Mail passenger train shall be utilized. • Vacuum brake equipped PCs currently used for Express/Mail passenger trains shall be used. • Introduction of air brakes shall be done taking opportunity of replacing aged rolling stock. EL: Replace WAM4 with WAP1. PC: Replace vacuum brake equipped coaches with air brake equipped coaches.	• WAM4 and vacuum brake equipped PC shall be used for the time being. (WAM1: Older than 21 years WAM4: Younger than 15 years.)
Fast freight train	• EL (WAG6) currently planned for new procurement.	• Current high-speed wagon. (BOXN, BCN, etc.)	——	• High-speed running test at 90 km is necessary for BOXN, BCN, etc.
Ordinary freight train	——	• EL (WAG5) for freight train • Air brake equipped wagon.	• Adoption of air brakes shall be executed when replacing aged rolling stock. EL: Replace WAG4 with WAG5. FW: Replace vacuum brake equipped wagons with air brake equipped wagons.	• WAG4 and vacuum brake equipped wagon shall be used for the time being. (Some trains may use WAG5 and air brake equipped wagons.) (WAG4: Older than 16 years.)

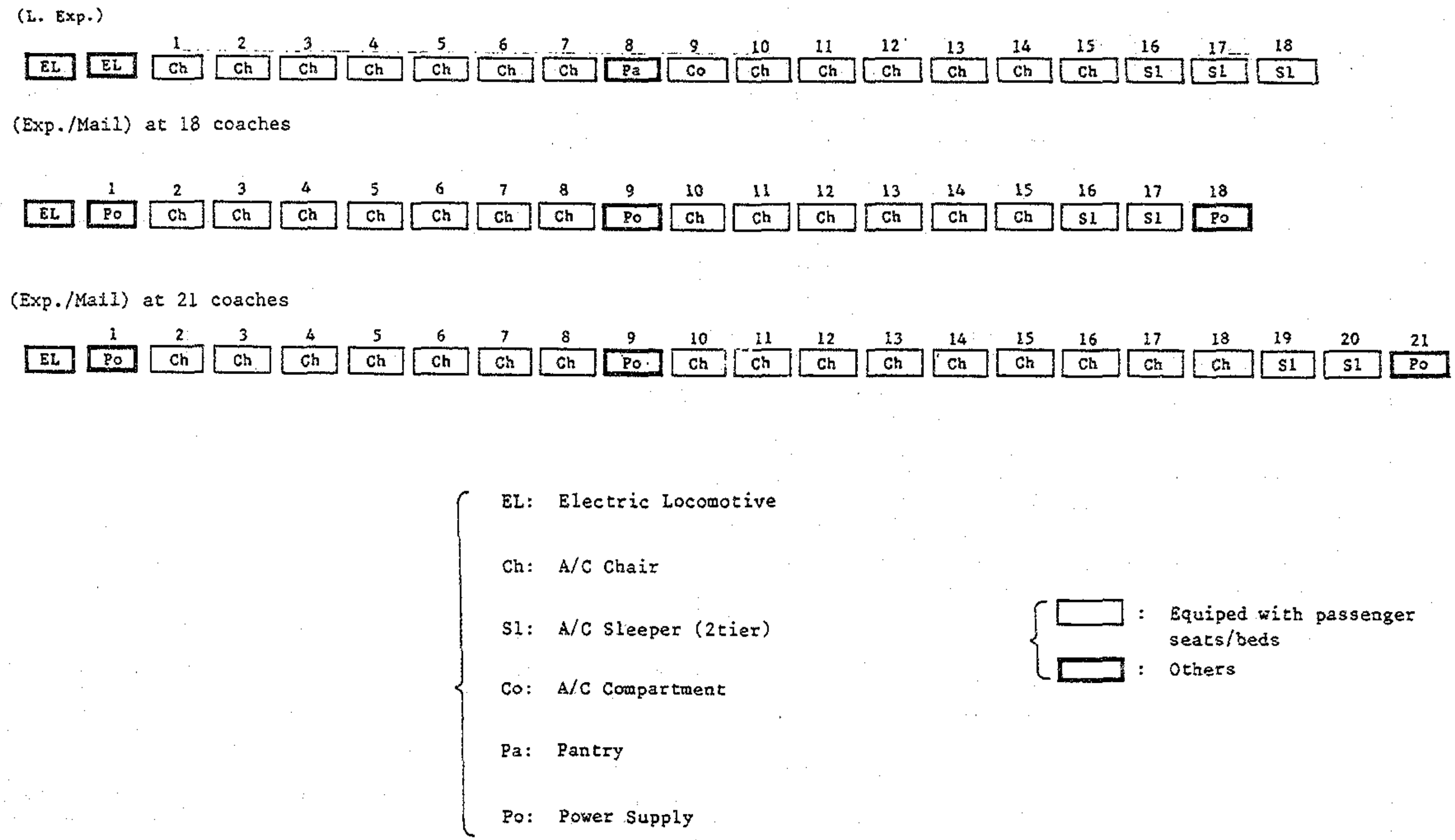


Fig. 4.3.4-1 Typical Formation of the L. Exp. and Exp./Mail Train

- The bogie frame will be simplified and its weight will be reduced to curb weight increase due to the enlarged traction motor capacity, facilitating its manufacturing and maintenance.

- Bolster will be dispensed with aiming at the same effects aforementioned, so the bolsterless type will be adopted (See Appendix 3-8).

. Traction motor drive

- As train speed goes up, the nose suspension device develops such problems as floating of the traction motor and worsened power transmission due to vibration, which together with large non-suspended weight adversely affects tracks.

  Therefore, flexible gear coupling method with motor mounted will be adopted, thereby improving safety and reducing adverse effects on tracks (See Appendix 3-9).

. Gear ratio

In the Bo-Bo type, since the traction motors are of the induction type and used at high speed revolution, a higher gear ratio should be adopted. (See Table 4.3.3-1.)

. Others

- To prevent cracks and damage on the bogie, structural improvement and changes of materials will be made.

- To improve riding comfort and safety, reduction in lateral force, stress concentration, and vibration frequency will be pursued.

b) High capacity traction motor

To enable high speed operation, the capacity of the traction motor will be increased to about 4,500 kW (760 kW x 6) or 3,500 kW (875 kW x 4).

c) Power control

- Thyristor phase control (Bo-Bo-Bo type)

  Train speed is smoothly controled by continuously changing traction voltage by means of the thyristor phase control technology. Adoption of this control will result in improved adhesion and readhesion at powering, so high acceleration can be obtained.

  Compared with tap control method, troubles due to cut-off of main current will decrease, so reduction in maintenance expenses can be expected owing to the above improvement as well as the non-existence of any mechanical part.

- 3-phase asynchronous power system and regenerative brake (Bo-Bo type)

  - The following improvements are expected by adoption of the induction motor:
  - Low maintenance cost and high reliability.
  - Large hauling capacity without increasing motive unit weight.
  - High re-adhesion performance at the time of wheel slippage.
  - Resistivity to higher revolution speed.
  - The capacity of the main transformer can be reduced by improving power-factor using GTOs.
  - Resistor is dispensed with by adoption of regenerative brake.
    (See Appendix 3-12).

d) Electromagnetic air brake

By dispatching brake commands to respective coaches electrically, the brake response time will be shortened. In case of a train composed of 18 coaches, response time will be improved by about 8 seconds, diminishing idle running time and shortening braking distance (See Appendix 3-10).

e) AWS device with speed check function

As safety measures to meet higher train speed and train density, the AWS device with speed check function will be installed in electric locomotives for L. Express trains.

f) Extra-high-tension cable laid through coupler

To prevent contact loss of pantographs, electric collection will be make through a single pantograph for multiple operation of 2 locomotives.

For this purpose, an electric coupler for extra-high-tension cable is installed between two electric locomotives.

2) Coach

a) Bogie for high speed train

To meet higher train speed, increased safety and enhanced riding comfort, prevention of cracks will be sought through structural improvement of a bogie and reduction in their weight.

b) Disc brake

Disc brakes will be adopted to prevent the blocking of brakes and to increase braking force (See Appendix 3-11).

c) Electromagnetic air brake

Magnetic valves for receiving electric commands from EL and transforming them into pneumatic commands for applying brakes will be installed in respective coaches, linking them with electric wires through couplers.

Conventional automatic air brakes will also be installed to allow hauling by conventional-type EL when trouble occurs in the "New Type EL". In addition, an electric coupler will be installed on the roof end of the coach to prevent it from being stolen.

d) Light-weight coach

The coach shall be of a light weight structure with stainless steel body and underframe. The bogie shall be of a bolster-less simple structure. The interior equipment shall also be lightweighted. As a result, coach weight of 33t can be attained (See Appendix 3-17).

(3) Exp./Mail passenger train

Eliminating two pantry cars and one A/C compartment car from the current Rajdhani Express Train, but adding 3 - 6 A/C chair cars instead, the train with larger carrying capacity will be made up. (See Table 4.3.2-1 and Fig. 4.3.4-1.)

1) EL

WAP1 type (Currently used for the Rajdhani Express Train.)

2) Coach

WACCW, WSCZAC, WLRRM type
(They are equipped with air brakes and currently used for the Rajdhani Express Train.)

(4) Local passenger trains

1) EL

WAM4 type (Currently used for Express/Mail Trains)
(Superannuated WAM4s will be replaced with WAP1s in future.)

2) Coach

a) Existing type of coaches equipped with vacuum brakes for Exp./Mail passenger train will be used.

b) The vacuum brakes will be replaced with air brakes when the existing rolling stock reaches the end of its service life.

(5) Fast freight train

1) EL

WAG6 type (WAG5 will be used for the time being with the reduced hauling tonnage.)

2) Wagon

Existing high-speed wagons equipped with air brakes will be used. (BOXN, BCN etc.)

(6) Ordinary freight train

1) EL

WAG5 and WAG4 type (Only WAG5 type equipped with air and vacuum brakes shall be procured anew.)

2) Wagon

a) Existing wagons equipped with vacuum brakes will be used. (CRT, CR, etc. will not be used.)

b) Newly procured wagons shall be equipped with air brakes. (To be used in combination with WAG5.)

4-4 Ground Facilities

4-4-1 Track and Structure

To improve train speed and track capacity, suitability of the current curves and grades, track structure, station facilities and other constructions are checked, and improvement plans are made as necessary.

To raise the effect of the abovementioned improvements, measures to eliminate the existing speed restrictions are also studied.

(1) Curve and grade

1) Curve and cant

The minimum radius of curvature (R) which allow train operation at 160km/h calculated based on the new standard of cant for the high-speed train operation proposed by IR is as follows.

Max. train speed	Vmax = 160 km/h
Max. cant	Ca = 180 mm
Max. deficiency permissible	Cd = 100 mm

$$R = \frac{13.67V^2 \text{ max.}}{Ca + Cd} = 1250 \text{ m}$$

Between Ghaziabad and Kanpur, there are 107 curves on the up line, and 123 curves on the down line. The radius of the above curvatures are all larger than 1250 m except the 1000 m curvature in the Tundla yard. This curve, however, is kept unchanged, since the overall change of the track layout is necessary. As for the other curves, cant and transition curve are improved. Improvement of cant is required for 70 curves with additional cant of the max. 38 mm.

Standards of cant in various countries are shown in the Appendix 4-1 for reference.

2) Transition curve

For the high-speed train operation at 160 km/h, improvement of transition curve length will become necessary in addition to the abovementioned resetting of cant.

The IR standard proposed for the new high-speed train operation is as follows.

$L_1 = 0.005Ca \times Vm$	L :	Transition length (m)
$L_2 = 0.005Cd \times Vm$	Vm:	Max. permissible speed (km/h)
$L_3 = 1.2Ca$	Cd:	Cant deficiency (mm)
	Ca:	Actual cant (mm)

The maximum value among $L_1 - L_3$ is used.

According to the calculation by the above formulas, 34 curves, whose total length is 7 km, must be improved.

The maximum extension length of the improved transition curve is 25 m on one side, and the maximum shift is the lateral direction is 39 mm. These curves are located out of station yards, so that their improvements will not be difficult. In putting the modification plan into practice, however, a detailed survey is requested. Appendix 4-13 shows the sections of transition curves to be improved.

For reference, standards of transition curve in various countries are shown in the Appendix 4-2.

The straight track length required between adjacent reverse curves is explained at the Appendix 4-3.

3) Grade and vertical curve

The track level on the Section is quite flat with a maximum grade of less than 5/1000 and the radius of vertical curvature at changing points of grades are greater than 4000 m. Therefore no problem is expected in the 160 km/h high-speed train operation.

Details of the vertical curve are described in the Appendix 4-4.

(2) Station and structure

On the section between Ghaziabad and Kanpur (about 413 km), there are 48 stations and 1 signal station. Most stations have loop lines longer than 685 m effective length.

Further, loop lines are to be constructed for all non-looped stations in the 7th 5-year plan.

To maximize the effectiveness of the 160 km/h high-speed train operation, it is necessary to remove the existing speed restrictions shown in Table 4.4.1-1. For the security of passengers and increasing the line capacity, additional loop lines and security fenses on the platforms should be constructed, and the turnouts on loop lines for freight train should be improved.

1) Station

"High-speed train operation at 160 km/h"

a) Aligarh station yard (Fig. 4.4.1-1)

At the Aligarh station, the up and down main lines adjoin the platform. For the passenger's security on the platform, therefore, the speed of run-through trains is limited to 100km/h. To solve this the platform and track layout should be changed so that 160 km/h high-speed trains can pass without adjoining the platform.

ALIGARH

(1,326.52)

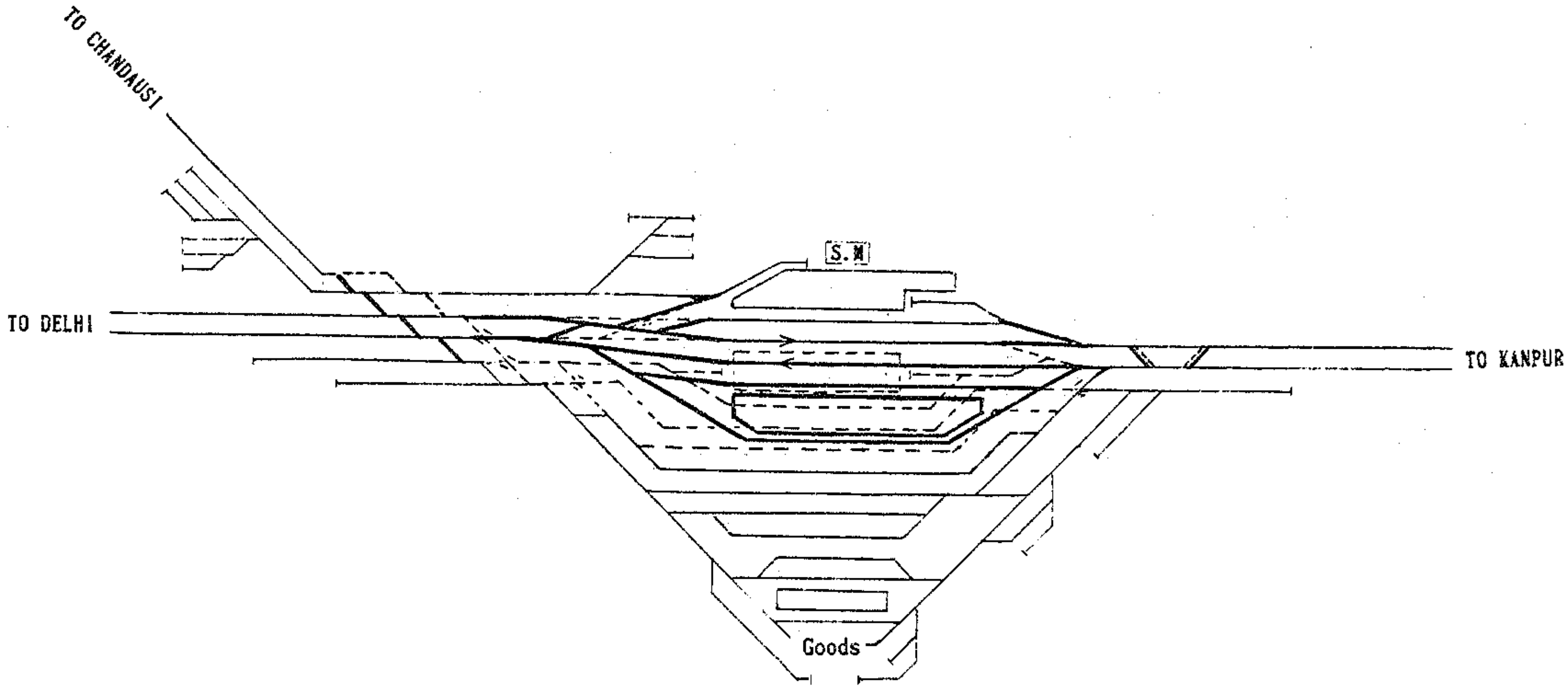


Fig. 4.4.1-1 Aligarh Station Yard Improvement Plan

Table 4.4.1-1 Speed Restrictions on the Section

Item \ Section	Speed restriction from	to	Speed	Cause
Up-Line	km	km	km/h	
Kanpur - Panki	Crossover		15	Crossover from North to South line.
Maitha - Rura	1054.2	1054.2	100	Multiple span girder Bridge No. 304
Etawah yard	1155.0	1156.1	100	Etawah major yard
Tundla yard	1248.5	1250.1	65	Diamond crossing with curves
Tundla - Mitawali	1250.3	1251.2	100	No transition length between two sharp compound curves
Hathras	1296.7	1296.9	110	Fly over bridge
Aligarh yard	1326.7	1327.3	100	Aligarh major yard
Down-Line				
Aligarh yard	1327.4	1326.8	100	Aligarh major yard
Hathras	1296.6	1296.1	100	Hathras major yard
Tundla yard	1250.2	1247.1	65	Diamond crossing with curves
Etawah yard	1156.1	1155.0	100	Etawah major yard
Rura - Maitha	1054.2	1054.2	100	Multiple span girder bridge No. 304
Panki yard	1029.2	1029.2	100	Large number of curves
Panki - Kanpur	Crossover		15	Crossover from South to North

b) Etawah station yard (Fig. 4.4.1-2)

At the Etawah station, main lines adjoin the platform. For the passenger's security, therefore, the run-through train speed is limited to 100 km/h. Improvement of the platform and track layout should be made so that 160 km/h high-speed train can run without adjoining the platform.

"Elimination of speed-restrictions"

c) Tundla station yard (Fig. 4.4.1-3)

At the Tundla station yard, train speed is restricted below 100 km/h or 65 km/h owing to the diamond crossings in the curve, two sharp compound curves, and ballastless track structure adjoining the platform. Therefore, the following improvement will be made.

i) The curve in the diamond crossing zone will be removed through track layout improvement.

ii) The alignment of the sharp compound curves will be improved to secure the necessary transition curve length.

iii) The structure of the ballastless track adjoining the platform will be strengthened.

With the aforementioned improvements, the run-through train speed can be raised up to 120 km/h. But in view of the following reasons, the run-through train speed at Tundla station will be restricted below 100 km/h.

- Construction of new run-through lines apart from platforms will require comprehensive change of track layout of the yard.
- On the platform with a large number of passengers, security fenses will hinder passengers to ride-on or get-off the train.

ETAWAH

(1,156.65)

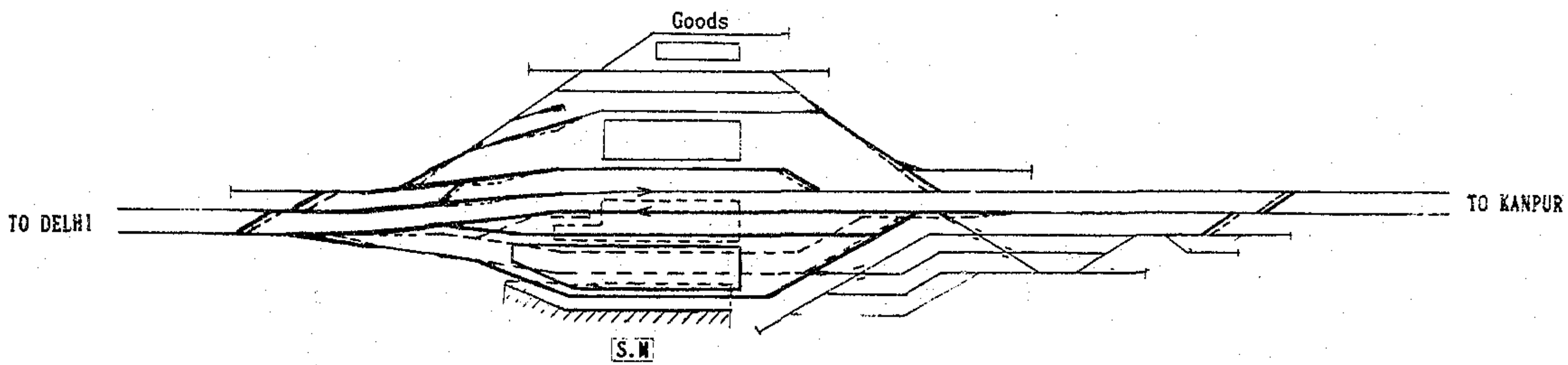


Fig. 4.4.1-2 Etawah Station Yard Improvement Plan

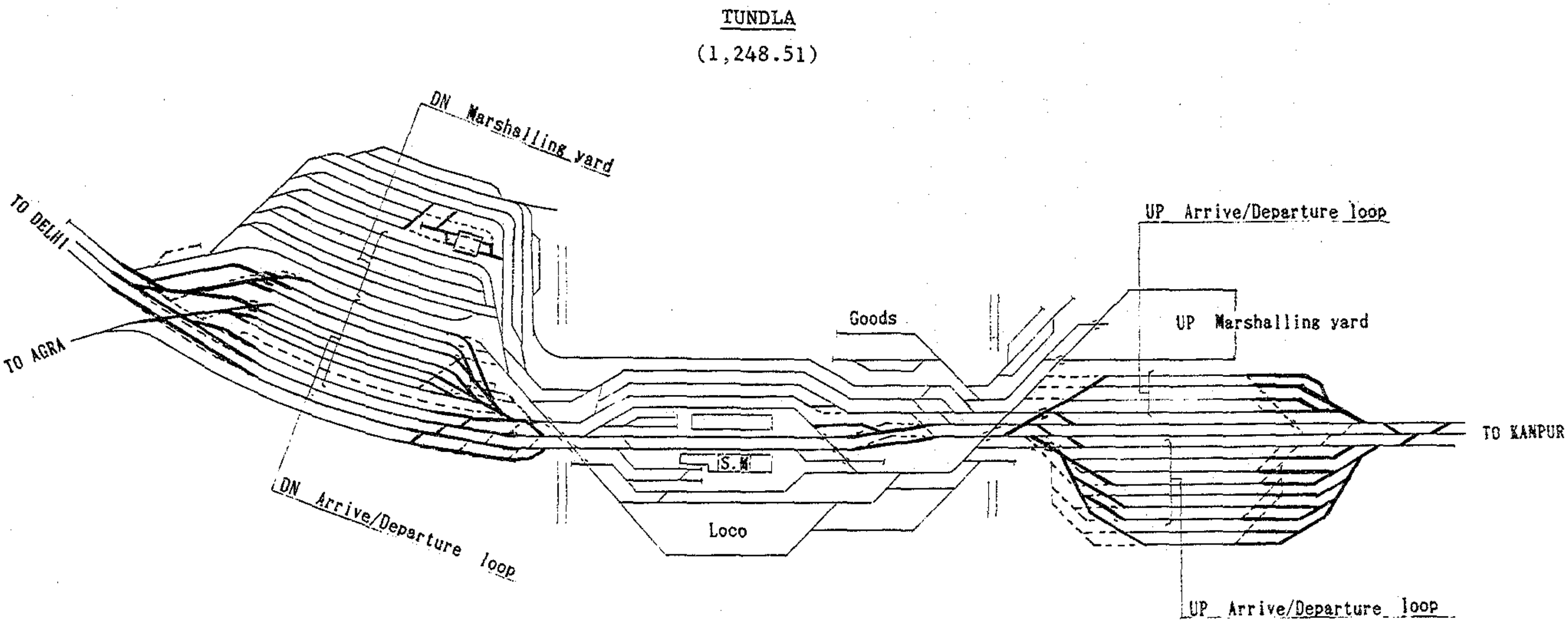


Fig. 4.4.1-3 Tundla Station Yard Improvement Plan

"Improvement of track capacity"

d) Kanpur station yard (Fig. 4.4.1-4)

To cope with the increase in the number of trains to be handled at the Kanpur station, and locomotive-changing-work for 160 km/h high-speed trains, 1 platform and 2 arrival/departure lines will be added utilizing the loops currently used for meter-gauge trains.

e) Ghaziabad, Tundla, and Juhi Yards

At the Ghaziabad, Tundla, and Juhi Yards, the freight train speed on the turnouts is limited to 10 km/h due to the use of 1 in $8\frac{1}{2}$ turnout. This increases the departing/arriving train operating time and necessitates to keep a long headway between the freight train and the following train, causing a bottleneck of track capacity. To solve this problem, at these 3 yards all turnouts on freight train departure/arrival loops will be replaced with a 1 in 12 turnout with a curve switch so that the speed limit can be raised to 40 km/h. This upgrading will reduce headway by 3 - 7 minutes at departure, and about 5 minutes at the arrival of a freight train as shown in Fig. 4.4.1-5, thus raising the track capacity.

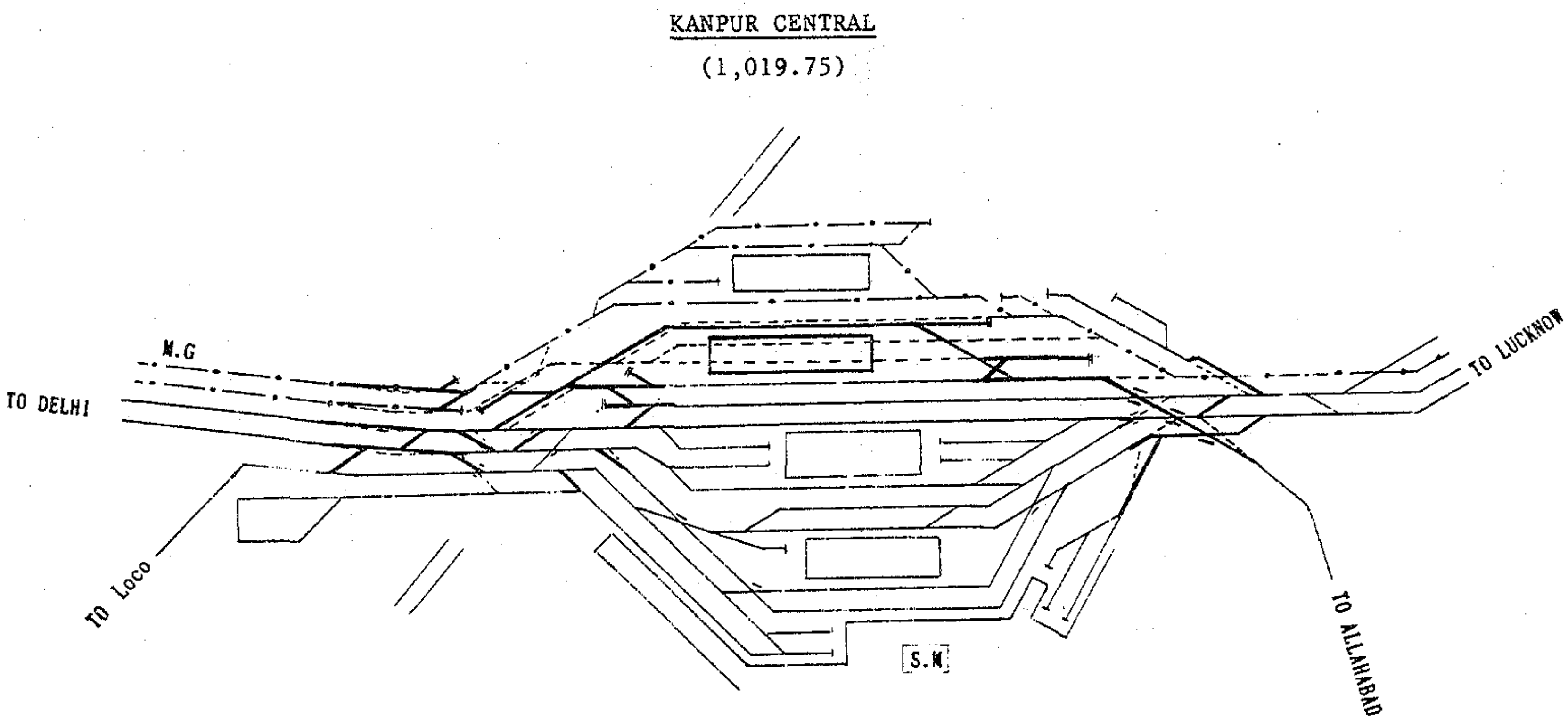


Fig. 4.4.1-4 Kanpur Central Station Yard Improvement Plan

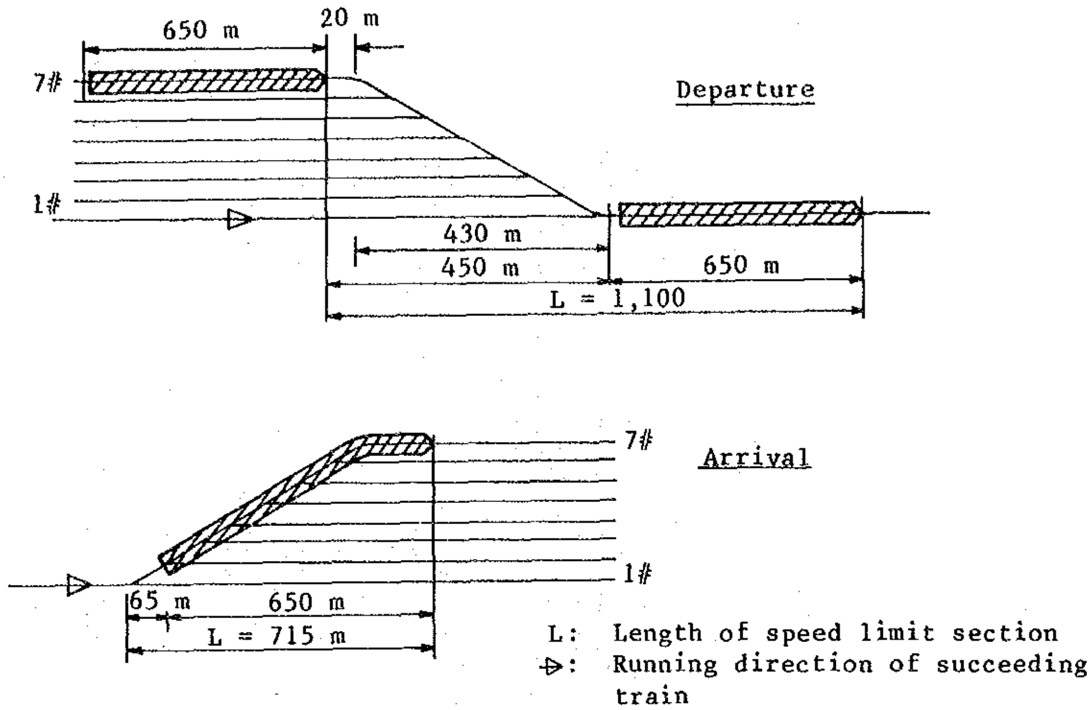


Fig. 4.4.1-5 Length of Speed Limit Section of the Departing/Arriving Freight Train

In the Ghaziabad yard, the turnouts on the Tundla side of the 13 departure/arrival loops are to be improved as shown in Fig. 4.4.1-6. In the Tundla yard, the turnouts in the front and rear of the 8 down loops on the Delhi side, and the 11 up loops on the Kanpur side shown in Fig. 4.4.1-3 are to be improved. In the Juhi Yard, the yard are to be improved by upgrading the turnouts in the front and rear side of the 14 up and down loops and of the access track as shown in Fig. 4.4.1-7. The reduction in train operating time achieved by these improvements are shown in Appendix 2-7.

2) Structure

A 110 km/h speed restriction is imposed on the Hathras fly-over bridge due to the lack of clearance. On the No. 304 bridge a 100 km/h speed restriction is imposed because of its multiple-span-girder structure.

To enable 160 km/h high-speed train operation, these two bridges will be improved.

GHAZIABAD

(1,432.35)

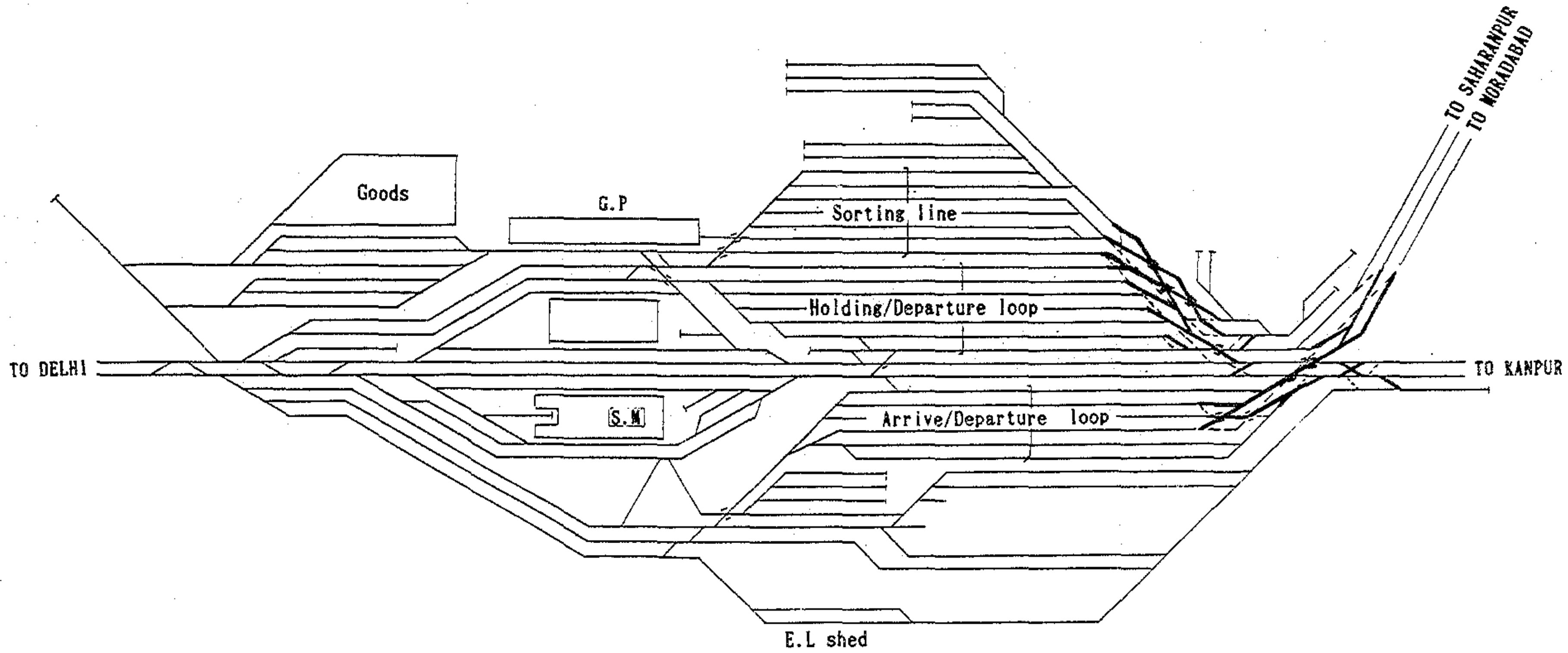


Fig. 4.4.1-6 Ghaziabad Station Yard Improvement Plan

JUHI MARSHALLING YARD

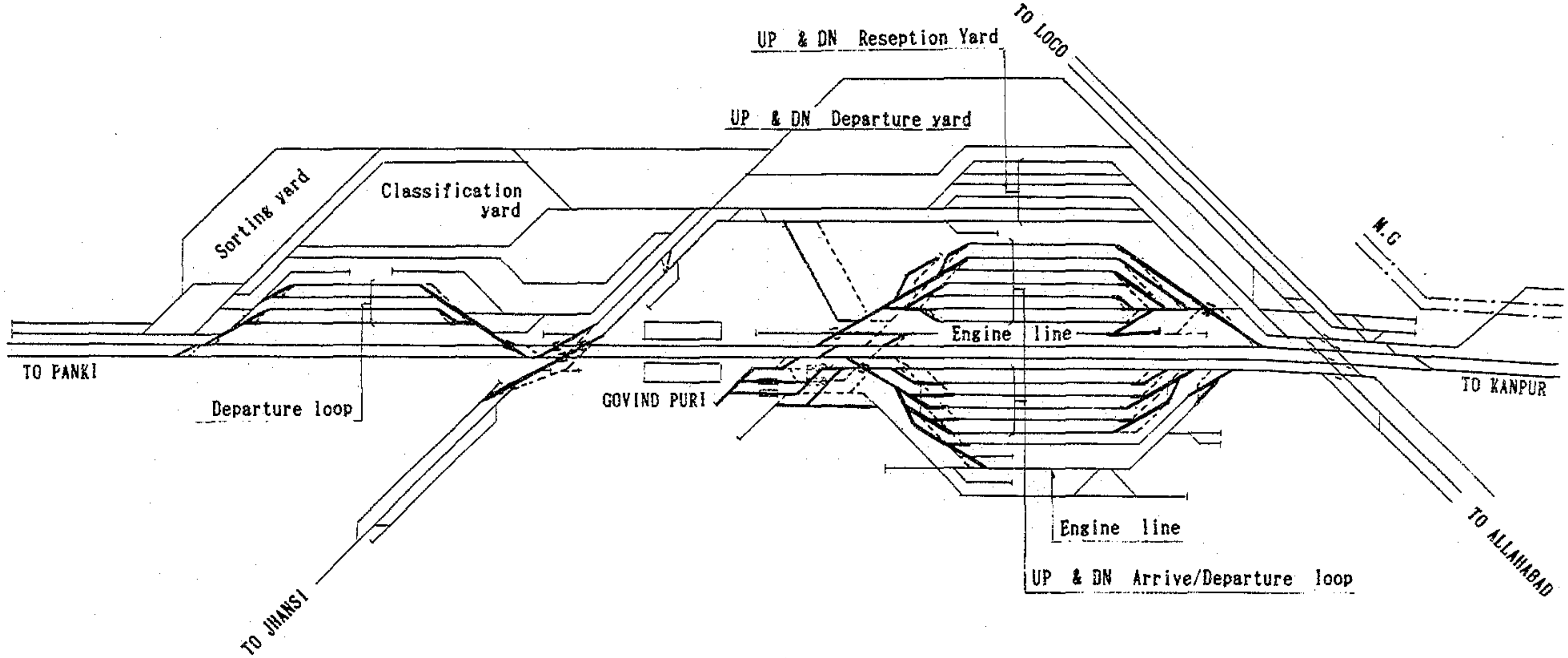


Fig. 4.4.1-7 Juhi Marshalling Yard Improvement Plan

To ensure safety during the passage of express trains running at 160 km/h, it is necessary to install simple fence to keep pedestrian and cattle away on both sides of the track.

The increase of impact force caused by the speed-up will not cause any trouble. Details are given in the Appendix 4-5.

(3) Track structure

1) Track

Track renewal work is now under way between Ghaziabad and Kanpur. The new structure is as follows.

Rail : 52 kg/m (UTS 70 kgf/mm2) continuous welded rail
Sleeper : PRC 1,540/km
Fastening: Pandrol type elastic rail clip
Ballast : Crushed stone ballast with 30 cm thick under sleepers

The progress of the track renewal work is as shown in Table 4.4.1-2.

Table 4.4.1-2 Renewal Work on Ghaziabad - Kanpur Section

Item	Total length	Renewal work		
		Completed and progress	Proposed '87 ∿ '88	Incomplete
52 kg/m Rail	km	km	km	km
Down-line	408.7	225.7	140.0	43.0
Up-line	408.7	403.7	5.0	0
Total	817.4	629.4	145.0	43.0
PRC Sleeper	km	km	km	km
Down-line	408.7	123.3	140.0	145.4
Up-line	408.7	285.5	31.7	91.5
Total	817.4	408.8	171.7	236.9

(As of September, 1987)

A simulation was carried out to find whether or not the new track structure has sufficient strength to withstand the 160 km/h high-speed train operation. For details, refer to the Appendix 4-6.

According to the simulation results, this track structure will withstand the 160 km/h high-speed train operation.

IR has already started the renewal work to upgrade to 1660 sleepers per kilometer and to the 60 kg/m rail on the Section. By this renewal, a further reinforced track will be achieved. This renewal work is highly desirable in view of the high-speed train operation and dense traffic in the future. For reference, rail replacement cycle in foreign countries are shown in the Appendix 4-7. Appendix 4-15 introduces detail of rail replacement cycle in Japan.

Considerable number of rail flaws are seen at welded parts of continuous welded rails on the Section. For reference, examples of the welding method used in Japan are shown in the Appendix 4-8.

2) Turnout

a) Problems of current turnout

The turnouts currently used in the Section are 1 in $8\frac{1}{2}$ and 1 in 12 of 90 lb or 52 kg rails. The structure standard is as follows.

i) The tongue rail is prepared by machining the same rail as the stock rail.

ii) The switch is of articulated type.

iii) The crossing is of fabricated type.

iv) The guard is of C-type. (The same kind of rail.)

In order to achieve stable high-speed running, the current turnout has the following problems.

i) Switch

Since the switch is of articulated type, the joint will be subjected to a large impact when a train runs over it at 160 km/h speed, which may cause flaws at the end of members such as bolts and rail ends.

If the members at the switch heel are damaged, the tongue rail may be disconnected.

ii) Crossing

Since the crossing is of fabricated type, bolts will be loosened with the impact from 160 km/h train. Consequently, the decreased clamping pressure between nose and wing rails will increase impact, leading to damages of crossing members.

With the 1 in $8\frac{1}{2}$ turnout, of large flare angle, the back lateral pressure becomes extremely high when a train runs over it at 160 km/h. As a result, bolts may be damaged due to a large force subjected.

iii) Guard

The current C-type guard is designed so that back lateral pressure on the guard rail is received with the bolts connecting the guard rail and the outside rail. Accordingly, at 160 km/h train running, an increased back lateral pressure will enlarge the stress on bolts and may cause flaws in them.

iv) Rail joint on main line

Ordinary joint is used for the main line rail. When a train runs over the joint at 160 km/h, an increased hammering of wheels on the rail joint may damage the rail end, joint bolts and fish plates.

General requirements of turnouts, is as shown in Appendix 4-9.

Appendix 4-17 introduces design of turnout in JR.

b) Improvement plan

To meet the 160 km/h high-speed train operation, the following improvement will be made.

i) To adopt elastic type switches.

ii) Pressure welded crossing or solid manganese steel crossing will be used, and front and back end joints will be welded or bonded.

iii) To use H-type guard.

iv) Welded joint will be used as far as possible for the main line rail.

IR is already planning to adopt the 60 kg/m Thick-web turnout, which will assure a strong turnout structure as a whole. To meet the new conditions of high-speed train at 160 km/h, however, the additional improvements of (ii), (iii) and (iv) are considered necessary.

For the 160 km/h operation in particular, it is a minimum requirement to employ elastic switch and an H-type guard rail.

c) Replacement plan

To achieve the 160 km/h high-speed train operation and raising the track capacity, approximately 330 turnouts are replaced with the following way.

"160 km/h high-speed train operation"

i) The existing turnouts on the main line where trains run at 160 km/h will be replaced with the 1 in 12 (60 kg) improved type turnouts.

"Track capacity increase"

ii) Principal turnouts on main lines and sub-main lines will be replaced with curved switches. This will raise the branch-off speed restriction from 10/15 km/h to 40 km/h.

iii) Principal turnouts on crossover will be replaced with higher numbered turnouts such as 1 in 20 of new specification on the Panki-Kanpur section where pararell single-track operation is made. This will raise the train speed on the crossover section from 15 km/h to 70 km/h.

The aforementioned improvements will allow the 160 km/h high-speed train operation between Ghaziabad and Kanpur, except in the Tundla station yard where the speed is restricted below 100 km/h, and the crossover between Panki and Kanpur where the speed is limited below 70 km/h. Moreover the increased branch-off speed and newly installed loop lines will improve the track capacity.

4-4-2 Signalling and Telecommunications

(1) Automatic signalling

1) Present situation

a) Block system

The block system between Ghaziabad and Kanpur is the absolute block system. In principle there exists one block between adjacent stations, but the 21 long inter-station sections are divided into 2 blocks by providing a manned block hut for each section. The block length varies from 4 to 10 km, with the average length of 6 - 7 km.

The signalling facilities are designed to allow twin single line operation between Panki and Kanpur Central.

The Delhi-Ghaziabad section is equipped with the double line automatic block system or the twin single line automatic block system. (See Fig. 4.4.2-1.)

b) Signal system

The signals on the absolute block section are composed of home, inner distant, distant, starter and advanced starter signals.

Signal indication is made in 3 aspects of G, Y, and R for the home and starter, G, YY, and Y for the distant signal, and in 2 aspects of G and R for the advanced starter.

(See Fig. 4.4.2-2.)

Block hut signals include home, inner distant and distant signals. At the inside of the home signal, a 400 m tolerance distance is prepared against overrunning.

Gate signals interlocked with a crossing barriers are installed at the point 180 m before the level crossings. In the rear of the gate signals, relevant inner distant signals and distant signals are installed.

In the automatic block section between Delhi and Ghaziabad, a 4 aspect system of G, YY, Y, and R is used. Its block length is approx. 800 m, having a 120 m overlap. (See Fig. 4.4.2-3)

The minimum visibility distance is 200 m, and a driver will operate the brake as soon as the locomotive passes by the signal.

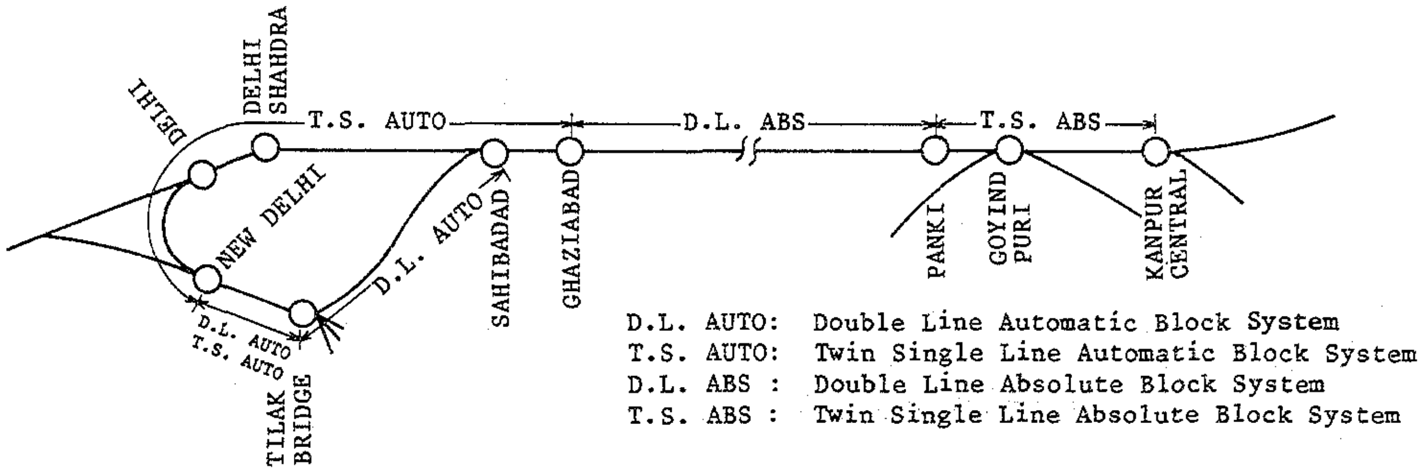


Fig. 4.4.2-1 Block System between Delhi and Kanpur

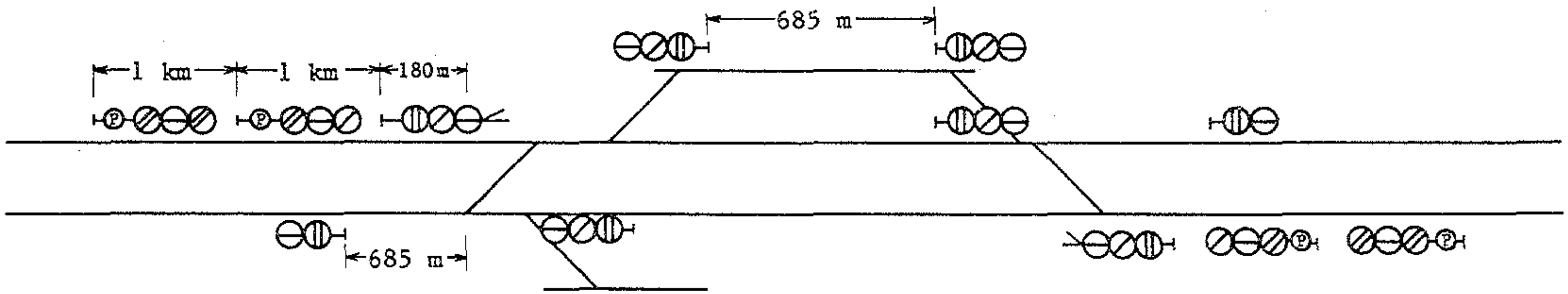


Fig. 4.4.2-2 Signals in Absolute Block Sections

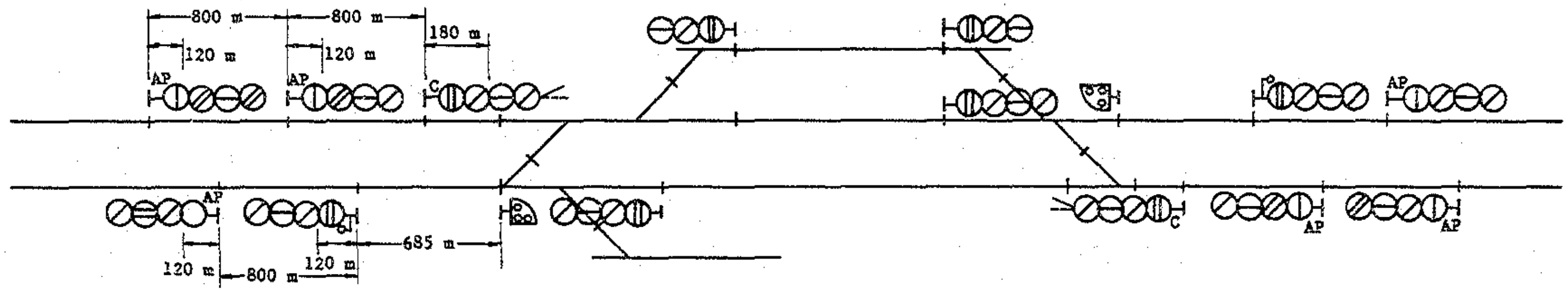


Fig. 4.4.2-3 Signals in Automatic Block Sections

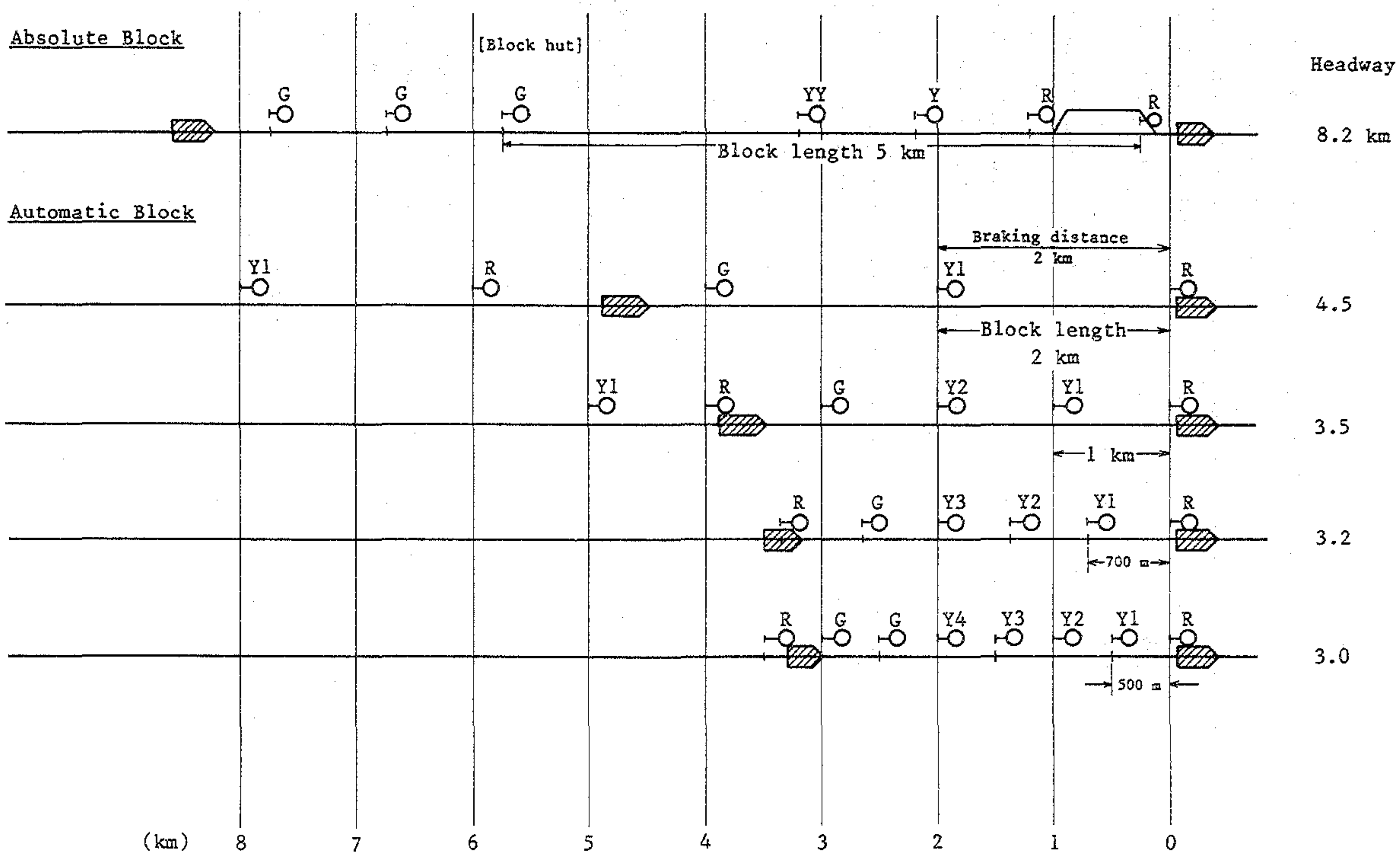


Fig. 4.4.2-4 Relation between Block Length and Headway

2) Wayside signal

In general, high-speed railways whose train speed are less than 200 km/h employ wayside signal system as seen in HST of U.K. In addition, considering the consistency with the signal indication system on the Section between Delhi and Ghaziabad, it will be appropriate to adopt wayside signal system for the 160 km/h high-speed trains operated between Ghaziabad and Kanpur. Since the minimum visibility distance is 200 m, a visible time of signal for the driver of 160 km/h train is about 5 sec. As it takes about 3 sec for the driver to start applying the brake after confirming the signal indication, the present visibility distance is theoretically enough for 160 km/h operation.

However, inview of the decrease in visible time compared with that of the 120 km/h operation and the longer visibility in the railways of various countries, it is advisable to improve the visibility distance for more than 200 m. (Refer to Appendix 5-18)

3) Automatic block system

a) Necessity of automatic block signalling

In order to cope with the future traffic increase, the automatic block system shall be introduced as a principal measures to enlarge the track capacity.

b) Block length

Since the max. braking distance is 2 km, a 1 km block length is considered the most adequate from the viewpoint of the headway shortening effect and the number of signal aspects. (See Fig. 4.4.2-4.)

In the Ghaziabad - Kanpur section, 120 m-overlap will be eliminated for the block signal to shorten the headway and reduce the investment cost.

This elimination is thought feasible for such reasons as,

- When the driver operates the brake on noticing the YY aspect, the train can stop within 2 km braking distance in the rear of the signal indicating the R aspect.
- Installation of AWS can prevent overrunning attributable to driver's misoperation.

c) Signal indication proposed

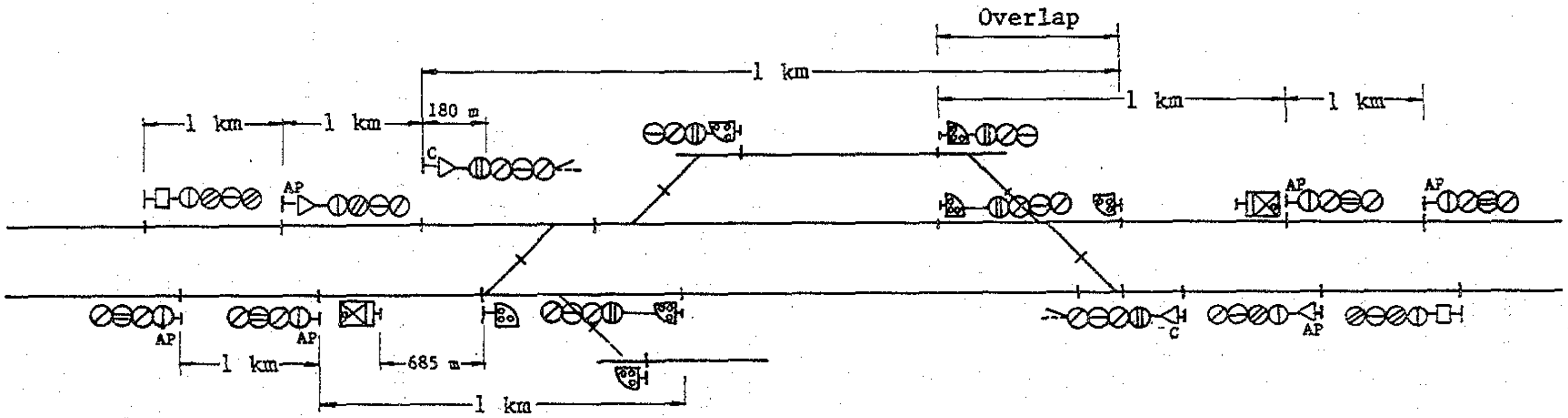
- In principal, 4 aspect method of G, YY, Y, and R will be adopted. However, in the case that the train runs into a loop line which has speed restriction at a turnout, it is difficult to decrease the train speed to the turnout limit speed if the brake is applied at the block signal indicating YY, which is in the rear of the home signal.

  To cope with this, the 5th aspect must be considered. An example of sequence of aspects recommended is YY + (Preliminary speed indicator), Y + speed indicator, YU + speed indicator, R. YU means Y + route indicator. Speed indicator will indicate various figures of turnout limit speed and preliminary speed indicator will be installed to the block signal indicating YY.

  Required function and construction of these indicators are shown in Appendix 5-10.

- The starter signal of the loop line will be of the 3 aspects of G, Y, and R.
- The distance between home and starter signals on the run-through line should be kept over 1 km. In case the current distance is less than 1 km, the overlap track circuit will be installed inside of the starter signal to secure 1 km.
- The block signals near the level crossings will be interlocked to them to function as gate signals.

The standardized signal locations according to the above concept are shown in Fig. 4.4.2-5.



Legend: Premilinary speed indicator
: Speed indicator

C : Calling on signal
Ap: Automatic permissible signal

Fig. 4.4.2-5 Proposed Signal Indication in Automatic Signalling System

(2) Train detection method

1) Present situation

As for train detection method on the automatic signalling section (Delhi-Ghaziabad) and the non-automatic signalling section (Ghaziabad-Kanpur), the single-rail DC track circuit is mainly used. Its control length is approx. 350 m when installed with the current P.S.C. sleeper. Partly, the axle counter is used on the steel sleeper sections, and the high-voltage impulse track circuit is used at station compounds subjected to DC disturbance current.

2) Improvement method

The automatic block length or track circuit length required in this project is 1 km as stated in (1)-3)-b).

To select the optimum train detection method to be applied for the automatic signalling, the following three methods are comparatively studied with regards to functions, electrical characteristics and construction cost. (Refer to Table 4.4.2-1)

a) Non-insulated audio-frequency track circuit (Ref. Appendix 5-2)

b) Low frequency code track circuit (80 Hz code) (Ref. Appendix 5-1)

c) Axle counter

Comparing the AF track circuit and the coded LF track circuit, the former has the following advantage over the latter.

i) Non-insulated track circuit can be composed, thus improving riding comfortability by use of jointless rail.

ii) Greater number of information can be transmitted to the cab, thus enabling introduction of cab signalling system.

iii) Concentration of field devices to the signal cabin is easy, thus enhancing maintenability.

iv) Small investment and better maintenability due to elimination of insulation joint and impedance-bond.

The axle counter system is more costly because countermeasures against erroneous detection by maintenance cars must be taken by, installing a short, non-insulated track circuit. Even in the case that this track circuit is eliminated by detecting the difference between wheel width of maintenance cars and that of trains, its cost will be still higher than track circuit systems. Besides, it can neither transmit information nor detect rail breakage. (Ref. Appendix 5-3)

As shown in Table 4.4.2-1, if the leakage conductance is maintained within I.R. standard value, 1 km control length of the non-insulated A.F track circuit is feasible without parallel condenser. If the above value is within 0 - 1.5 s/km, the same control length is feasible with parallel condenser. (Refer to Appendix 5-2)

For the above reasons, the Non-insulated A.F. track circuit is considered as most feasible.

In this context, the follwing two points are pointed out:

In order to keep the leakage conductance of the track circuit within the standard value (station compounds: 0.5 s/km i.e. insulation resistance of sleeper between inserts min. 3.3 K*/sleeper; block section: 0.25 s/km i.e. min 6.6 K*/sleeper - SIGNAL ENG. MANUAL 907-b), it is recommended to improve the insulation characteristics of the P.S.C. sleeper. (Refer to Appendix 4-24.)

There are some sections where steel sleepers are used (about 18% of the total section).

Steel sleepers have to be replaced with P.S.C. sleepers at general sections and wooden sleepers at point zone.

Table 4.4.2-1 Comparison of Train Detection Methods (Control length 1 km)

Classification / Item	Method / Detail	Non-insulated A.F. track circuit (2.5 kHz - 3.0 kHz)	L.F. track circuit (80 Hz)	Axle counter
Condition	Variable range of leakage conductance	0 - 1.5 s/km (With parallel condenser) 0 - 0.5 s/km	0 - 2.0 s/km	
	Shunting sensitivity or max. miscount rate	0.5 Ω	0.5 Ω	$1/10^6$
Function & characteristics	Rail breakage detection	Possible	Possible	Impossible
	Transmission of multiple information	Several	a few	Impossible
	Non-insulation	Possible	Difficult	
Economy	Cost ratio	1.2 (With parallel condenser) 1.0	1.4	1.9 (Without track circuit) 4.0 (With track circuit)

(3) Level crossing control method

1) Present situation and problems

There are 166 level crossings in every 2 - 3 km on average between Ghaziabad and Kanpur. (See Appendix 4-14 and 5-8)

These are all manned, and each of them is equipped with a telephone for communicating with adjacent stations, and those at heavy traffic roads are interlocked with gate signals. Some of them are equipped with train approaching warning bells.

With the existing level crossing system, it takes 5 - 6 minutes for a gateman to manually lower gates/barriers and to indicate the proceed signal on the gate signal, since getting aware of a train approach by telephone.

Therefore, the gate closing time will expand in proportion to increase in number of train and speed, supposedly bringing about serious disturbance to the road traffic.

2) Improving method

A new level crossing equipment will be controlled by the conventional gate signal method in consideration of the chaotic road traffic condition in India. In order to reduce hindrance to road traffic to the utmost, equalization and shortening of crossing-closing time is sought.

a) Fundamental concept

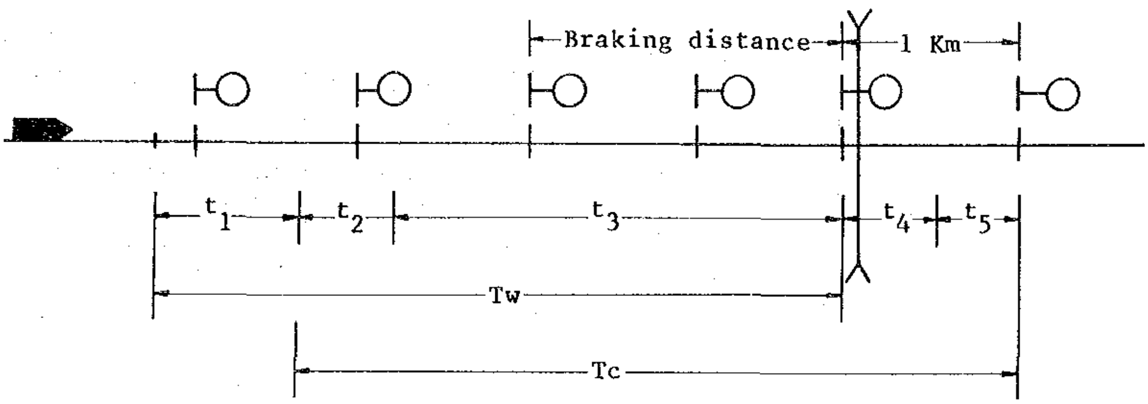
The current gate signal system should be improved to keep gate closing time uniform regardless of the train speed and to shorten barrier operation time, aiming at minimizing the disturbance of road traffic.

b) Control system

This system will detect the train speed, approaching the crossing, and control the alarm-start timing, so that the alarm time Tw, which means the time from alarm start until the train's arrival at the crossing, will be kept constant. (See Fig. 4.4.2-6.)

As for the train speed detection method, the track circuit or the axle counter can be utilized. In this plan, the former is adopted since it allows continuous detection of train speed and is more economical. To provide necessary control function to the equipment, microcomputer is used.

The system configuration of the continuous-speed-detection method by track circuit and spot speed detection method by axle counter are explained in Appendix 5-4.



Barrier closing time = Tc = $(t_2 + t_3 + t_4 + t_5)$

Alarming time = Tw = $(t_1 + t_2 + t_3)$

t_1: After alarm start till barrier lowering start

t_2: Barrier lowering time

t_3: After closing till train's arrival

t_4: Train-passing time through the crossing

t_5: Barrier rising time

Fig. 4.4.2-6 Time Sequence of a Barrier Control

c) Road traffic suspension time

Simulating based on the standard pattern diagram of operating five types of trains with average headway of 7.8 minutes as shown in the Table 4.4.2-2 which represents the heaviest traffic in the year of 2000, the road traffic suspension rate (η) amounts to nearly 50 percent, with the conditions of Tw = 2 min., t_2 = 10 sec. and t_5 = 18 sec. This implies that in 2000 when around 200 trains are operated in a day, level crossing will be closed for half of the train-operation timezone. In that stage some level crossings with very heavy road traffic will have to be converted into flyover bridges.

Table 4.4.2-2 Road Traffic Suspension Time Based on a Standard Pattern Diagram in 2000 (Average Headway of 7.8 min)

Type of train				Barrier closing time			Road traffic suspension time	
Max. speed (km/h)	F/P	No. of train (Ni)	Length (m)	(t2+t3) (min)	(t_4+t_5) (min)	Tci (min)	NiTci (min)	ΣNiTci (min)
75	F	7	402	1.87	0.62	2.49	17.43	71.34
90	F	7	422	1.87	0.71	2.58	18.06	
105	P	2	621	1.87	0.54	2.41	4.82	
130	P	12	421	1.87	0.52	2.39	28.68	
160	P	1	449	1.87	0.48	2.35	2.35	
	Total 29							

F: Freight Train
P: Passenger Train

The Road traffic suspension rate η can be obtained from the above table as follows:

$\Sigma NiTci = 71.34$ min.

$$\therefore \eta = \alpha \times \frac{\Sigma NiTci}{Tu} = 1.5 \times \frac{71.34}{226}$$

$= 47.3\%$

Where, α: Overlapping rate of up and down trains (1.5)

Tu: 1 cycle time of standard pattern

(Tu = 7.8 min. x 29 = 226 min.)

Correlation between train traffic and road suspension rate for "with" and "without" fixed-time barrier closing method and conventional manual control method are shown in Fig. 4.4.2-7. As shown in the figure, if fixed time alarming method is not adopted, the road traffic suspension rate will amount to 70% in 2000. With conventional manual control method, it will reach as much as 93%.

Comparison among this system, the present Indian one and the Japanese one are shown in Appendix 5-9.

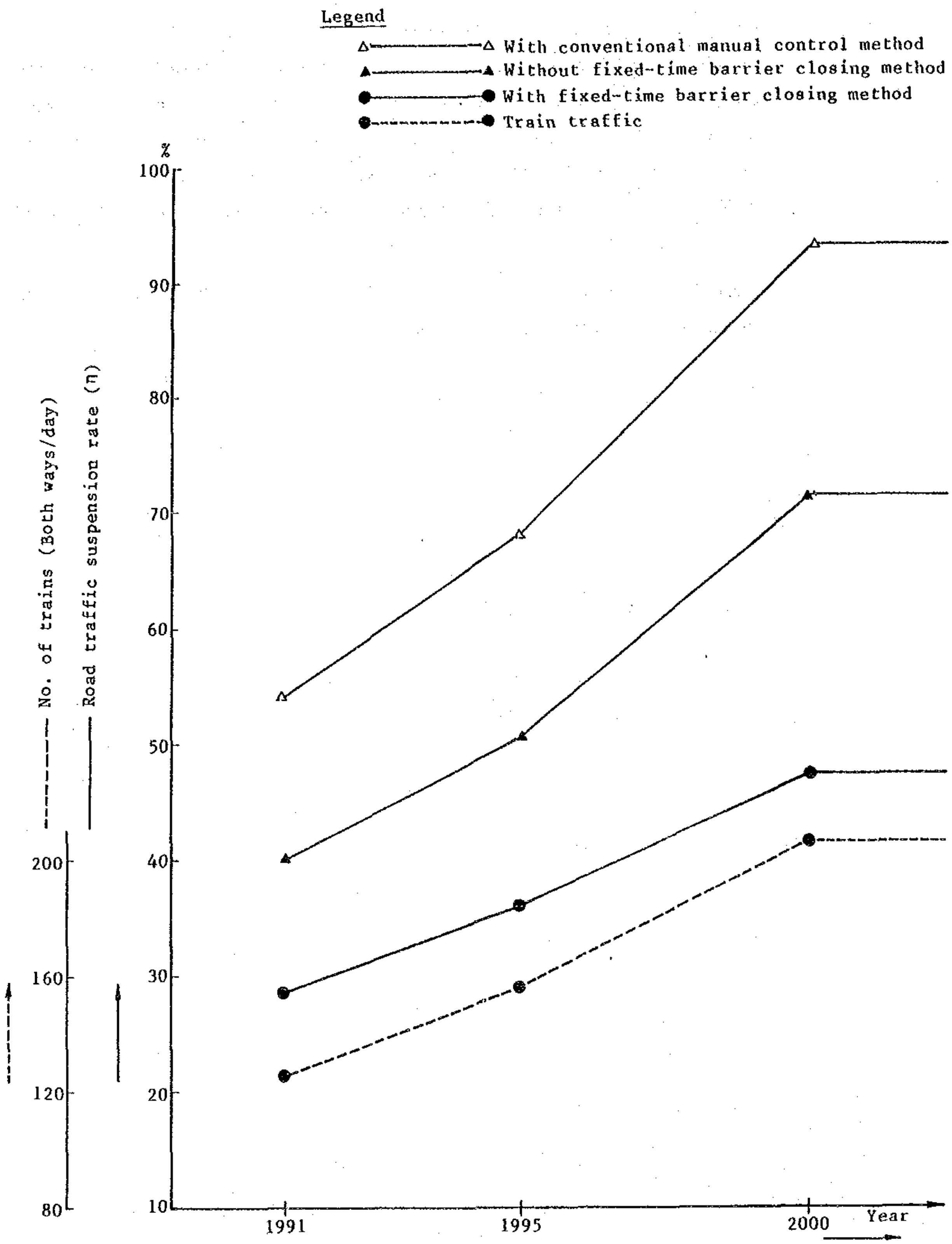


Fig. 4.4.2-7 <u>Correlation between Train-Traffic & Road Traffic Suspension Rate</u>

(4) Train protection system

1) Necessity

As the train speed and service density increase, it grows more difficult to secure safety in the train operation, if the safety depends only on engine driver's attention.

In the railway section of this Plan, maximum 160 km/h train operation is planned, and over 200 trains will be put into service. There will be even a larger number of trains serving between Delhi and Ghaziabad. Therefore, it is advisable to introduce train protection system on the Section.

2) Protection system

Train protection system or train speed control system can roughly be classified into two types. That is, one is the system to back up the train driver and automatically brake at danger (below referred to as AWS as called by IR) and the other is the system to make the optimum train speed control in place of the driver (ATC).

Observing railways of various countries, subways and railways with heavy traffic or high speed service of over 200 km/h use the ATC cab-signalling system. In other railways, AWS is generally used in combination with wayside signals.

Accordingly, AWS shall be adopted for the Project. The major AWS systems and their application examples are shown in Appendix 5-16.

The train operation in the Section has the following features.

- The train speed varies from 75 km/h to 160 km/h.
- The braking distance varies within the maximum length of 2 km.
- Branch-off and run-through train speed are restricted at turnouts and platforms.
- Locomotives are commonly used with other railways lines.

Considering these points and the future expansion of AWS application to other sections, the on-board speed checking intermittent control method is considered the best and most economical, since it can be applied to the sections without track circuits. For information transmission between ground and cab, the transponder which can mutually transmit various information is considered most suitable.

The transponder-based AWS system recently introduced in the Bombay area is applicable to the GZB - CNB section. For reference, a AWS system which transmits more kinds of information, such as distance to the stop signal, down gradient speed restriction and distance to the down gradient, to control the train speed more precisely is shown in Appendix 5-5.

3) Function

The outline of the AWS system based on the existing system in the Bombay area (RDSO/SPN/S-74/87) is shown in Fig. 4.4.2-8. The functions are described according to the figure.

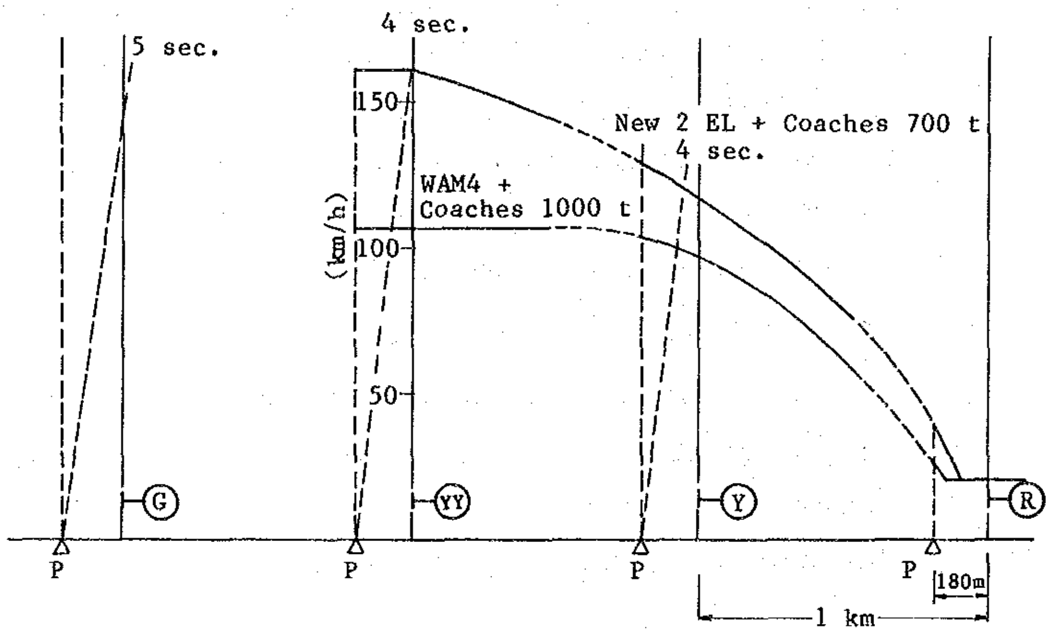


Fig. 4.4.2-8 Outline of AWS

- The wayside coil P is placed at a point 180 m apart from the outside of the signal. (160 km/h ÷ 3600 x 4 sec ≒ 180 m)
- When a train passes over P, with a wayside signal indication of G, the G indication will be repeated on board for 5 seconds.
- If the wayside signal is YY, when a train passes over P, information of YY is given with an alarm to the cab, and speed pattern is generated on board. If the driver depresses the acknowledgement button within 4 seconds, service braking is effected only when the train speed is faster than the pattern speed. If the acknowledgement button is not depressed, emergency braking is effected. The speed pattern should be in accordance with the braking characteristics of the train.
- If the signal is Y, when the train passes over P, on-board indication of Y and alarm, speed pattern generation corresponding to Y, and brake control are executed in the same manner as case of YY.
- If the signal is R, when the train passes over P, emergency braking is effected immediately, if the train speed is faster than the pattern speed.
- When the train comes to a stop with emergency braking, the train can not start unless the emergency stop confirmation button is depressed.

As described above, the transponder device transmits signal aspect information to the cab.

The above is the fundamental function of AWS, but the control method in the station compound is a little different as is described below.

- When the home signal indicates YU, P of the Y and YY signals, and home signal transmit information to the cab to generate a turnout speed pattern on board as shown in Fig. 4.4.2-9.

- Right below the home signal and the starting signals are placed wayside coils Pa. If the signal is R, emergency braking is immediately effected by receiving absolute stop information Ra.

Nos. of necessary information for above mentioned control method is 14. They are G, YY, Y, R, Ra for signal indications and YY+70, YY+40, YY+15, Y+70, Y+40, Y+15, YU+70, YU+40, YU+15 for turnout limit speed information.

As the Bombay AWS system transmits max. 21 informatin, it will be feasible to apply it to the AWS in the Section.

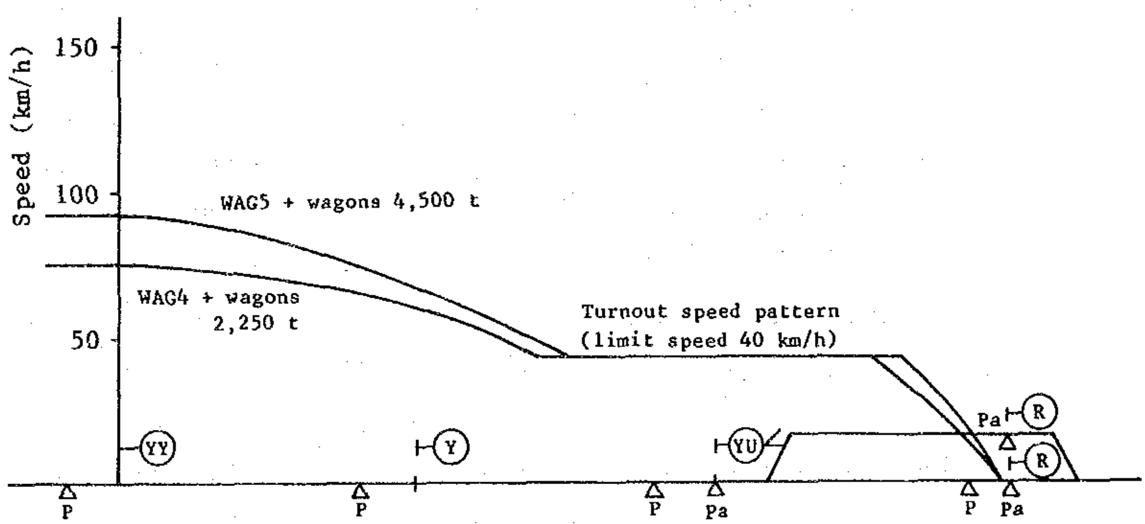


Fig. 4.4.2-9 Example of Speed Control Pattern at a Switching Point

The problem with this system is that it cannot follow the change of signal aspect continuously. Since many crossing barriers and signals are interlocked, it may often happen that, after a train's passing through the YY signal, the next signal will change from Y to G. In such a case, the train cannot raise the speed until it passes the transponder of the next signal.

To minimize such speed restriction, additional transponders will be installed at approaches to the level crossings and subsequently in block sections.

4) Improvement plan

a) On-board device

<u>Initial stage</u>

- L. distance train will be equipped with AWS.

<u>2nd stage</u>

- Other trains will be equipped with AWS in accordance with train traffic increase.

b) Ground device

<u>Initial stage</u>

- GZB-CNB section

<u>2nd stage</u>

- Delhi-GZB section

(5) Interlocking equipment

1) Present situation

There are 50 stations and 21 block huts between Ghaziabad and Kanpur (including Ghaziabad Station) (Fig. 4.4.2-10). Among these, 3 stations are equipped with route relay interlocking, 9 with panel interlocking, and the others are a mechanical interlocking with lever frame. All the block huts are with panel interlocking. A few stations with aged mechanical interlocking are converted to relay interlocking every year.

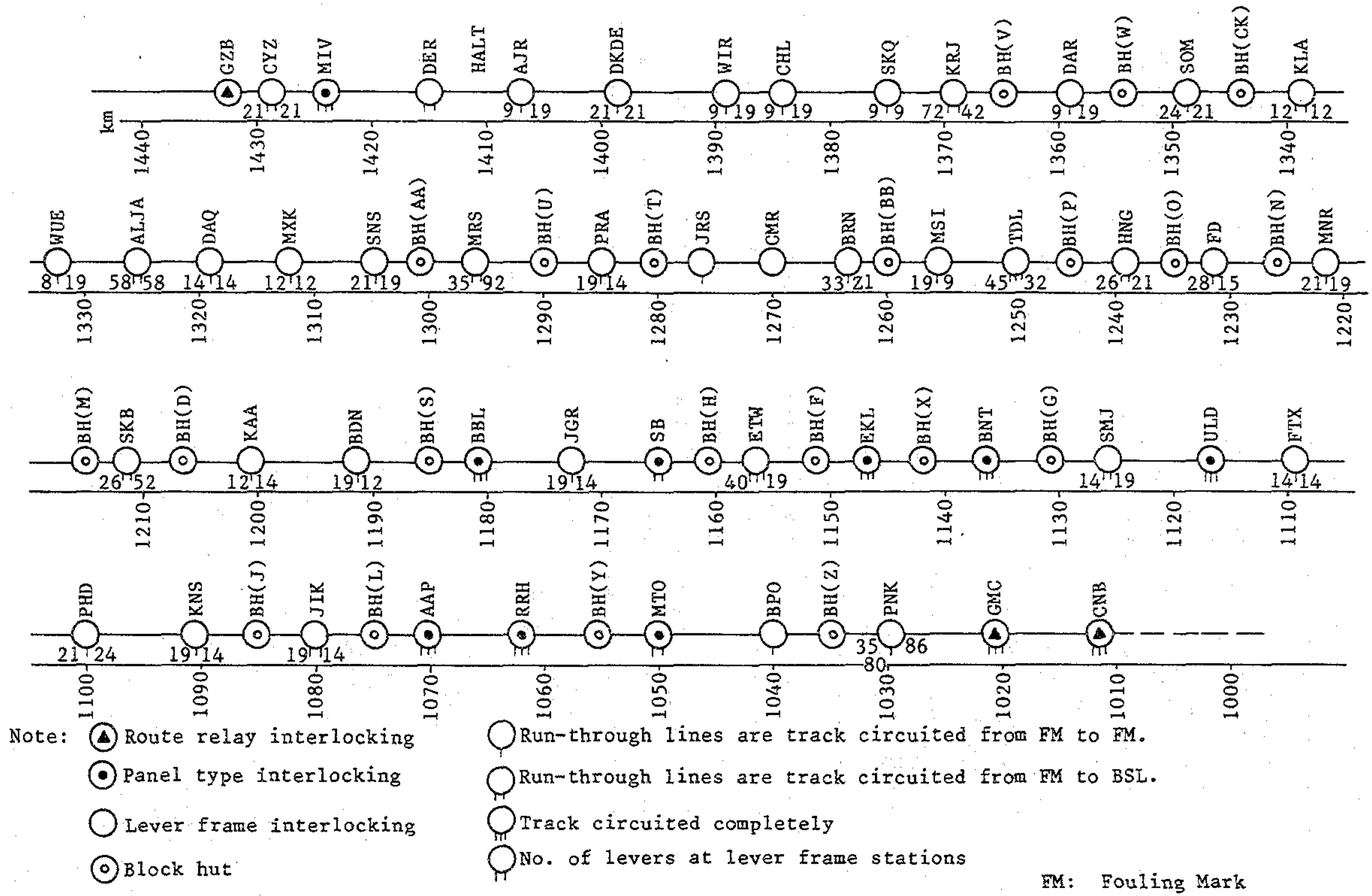


Fig. 4.4.2-10 Type of Interlocking Equipment at Each Station

2) Necessity of improvement

Considering the following problems, upgrading of the mechanical interlocking is considered necessary.

- At a lever frame station, as the number of trains increases, route setting will take more time for lever operation and communication interlocking between related signal cabins. This will cause a serious hindrance in increasing the track capacity.
- Considerable modification of the existing mechanical interlocking devices will be necessary according to the conversion of turnout from No. 8.5 to No. 12, provision of automatic signalling as well as reinforcement of locking devices of switches to enable 160 km/h train operation. (Ref. Appendix 5-19.)

3) Adoption of solid-state interlocking device

Recently, the solid-state interlocking device with superior functions to the conventional relay interlocking device, has been introduced for some advanced railways. A drastic improvement of solid-state interlocking device is expected to be achieved in the next few years both in performance and cost in the course of the rapid progress of micro-electronic technology. In this project, therefore, the solid-state interlocking device shall be adopted. (Ref. Appendix 5-6)

(6) Train traffic control

1) Necessity of improvement

With present train dispatcher system, one dispatcher takes charge of various works such as collection, recording, judgement, and dispatching traffic control order to the related trains. However, with the current communication system mainly using control telephone as a sole media, it may be very difficult to promptly collect necessary information from wide range of source, and immediately transmit appropriate orders to them in case of a large scale of traffic disorder.

Considering the further complication of the train operation caused by the increase in number and speed of trains in the future, prompt and optimum train traffic control is expected to become more difficult.

Under the circumstances, it is necessary to introduce the undermentioned traffic control system to improve the train traffic control job.

2) Contents of improvement

a) Prerequisite

i) Control center will be located at Tundla.

ii) The station should be furnished with the relay or the solid-state interlocking equipment.

iii) Measures to keep consistency with the train traffic control system planned at Delhi area will be taken.

iv) Train number input terminal will be installed at Tundla, Kanpur, Ghaziabad, Khurja, Aligarh, Hathras, Barhan, Shikohabad and Juhi stations to input incoming/outgoing trains' number from/to other branch lines.

v) Transmission channels will be secured for CTC, i.e. 2-4 channels in the microwave link and 2 channels in the underground cable.

b) System outline

- At the Tundla control center, train running information of all the trains will be displayed on the indication panel so that the dispatcher can always grasp the overall traffic situation. In addition to this, the automatic train diagram recorder is installed to release the dispatcher from manual recording works.

- At ordinary stations, train route will be remote controlled from the center.

- The traffic control function of dispatcher is to be improved by introduction of the train information indicator having various indication functions such as delay-time, delay-warning and train number change.

- At every station, the above devices will be installed so that train number input, change or cancellation of train operation schedule can be made, and necessary train traffic information can be obtained.

- At major stations, in addition to the aforementioned device, passenger information displays will be installed to upgrade information service for passengers.

  (Ref. Fig. 4.4.2-11, 4.4.2-12)

- Traffic information between Sahibabad and Ghaziabad stations will be transmitted from C.T.C centre of Delhi area to the Tundla control centre and displayed on the indication pannel to improve dispatchers' train traffic control capabilities and facilitate handling of passenger enquiries.

  In the same way, traffic information between Ghaziabad and Khurja stations will be fed back from Tundla CTC centre to the C.T.C centre of Delhi area. (Refer to Fig. 4.4.2-13)

- Key Board Video Display Units (V.D.U) with communication interface will be provided to such peripheral stations as Unaao, Fatehpur, Yamuna-Bridge and Bhimsen (JN.) in the Section to enable these stations to transmit advance train information to the Tundla control center.

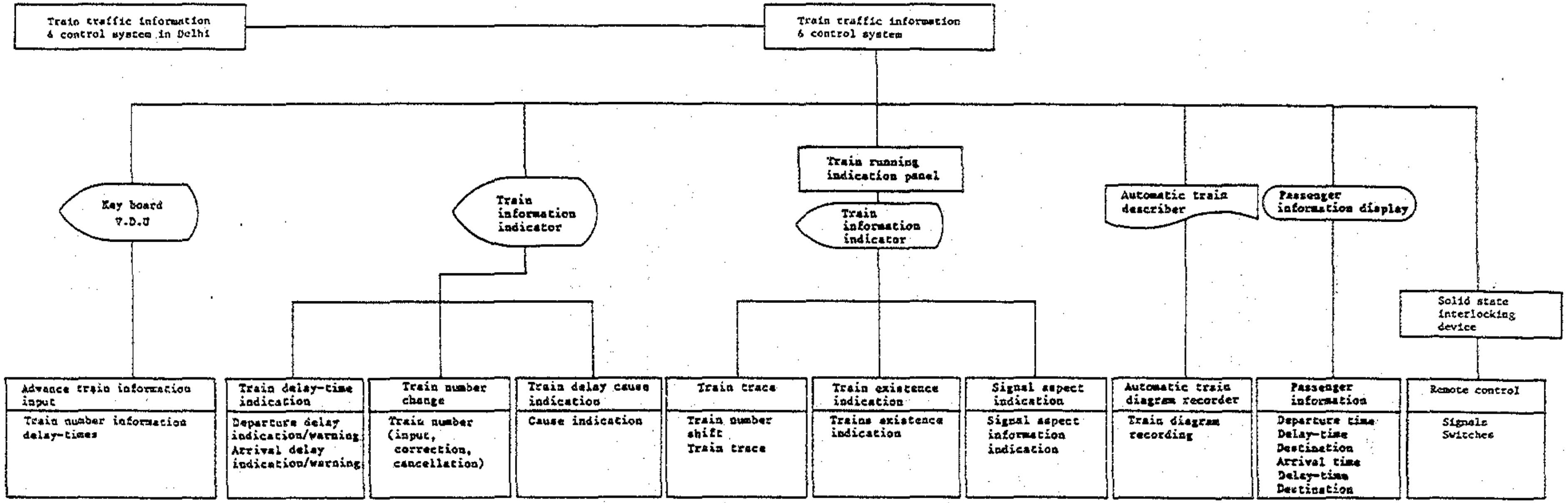
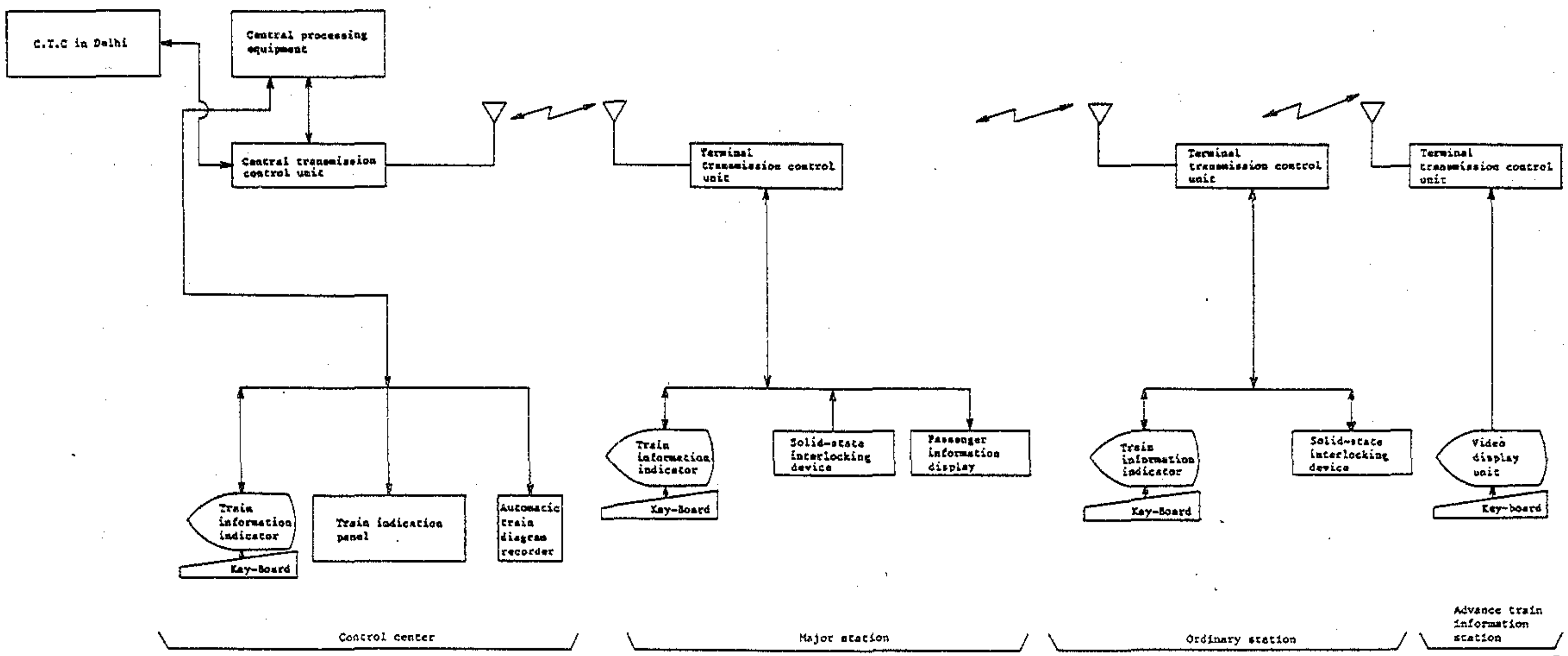


Fig. 4.4.2-11 General Functions of Train Traffic Information System



	Control center	Major stations	Ordinary stations	Advance train information stations
Name of stations	Tundla	Ghaziabad Khurja Aligarh Hathras Tundla Shikohabad Etawah Panki Kanpur	Way stations except Major stations	Yamuna-bridge Bhimsen Fatehpur Unnao

Fig. 4.4.2-12 Configuration of Train Traffic Information System

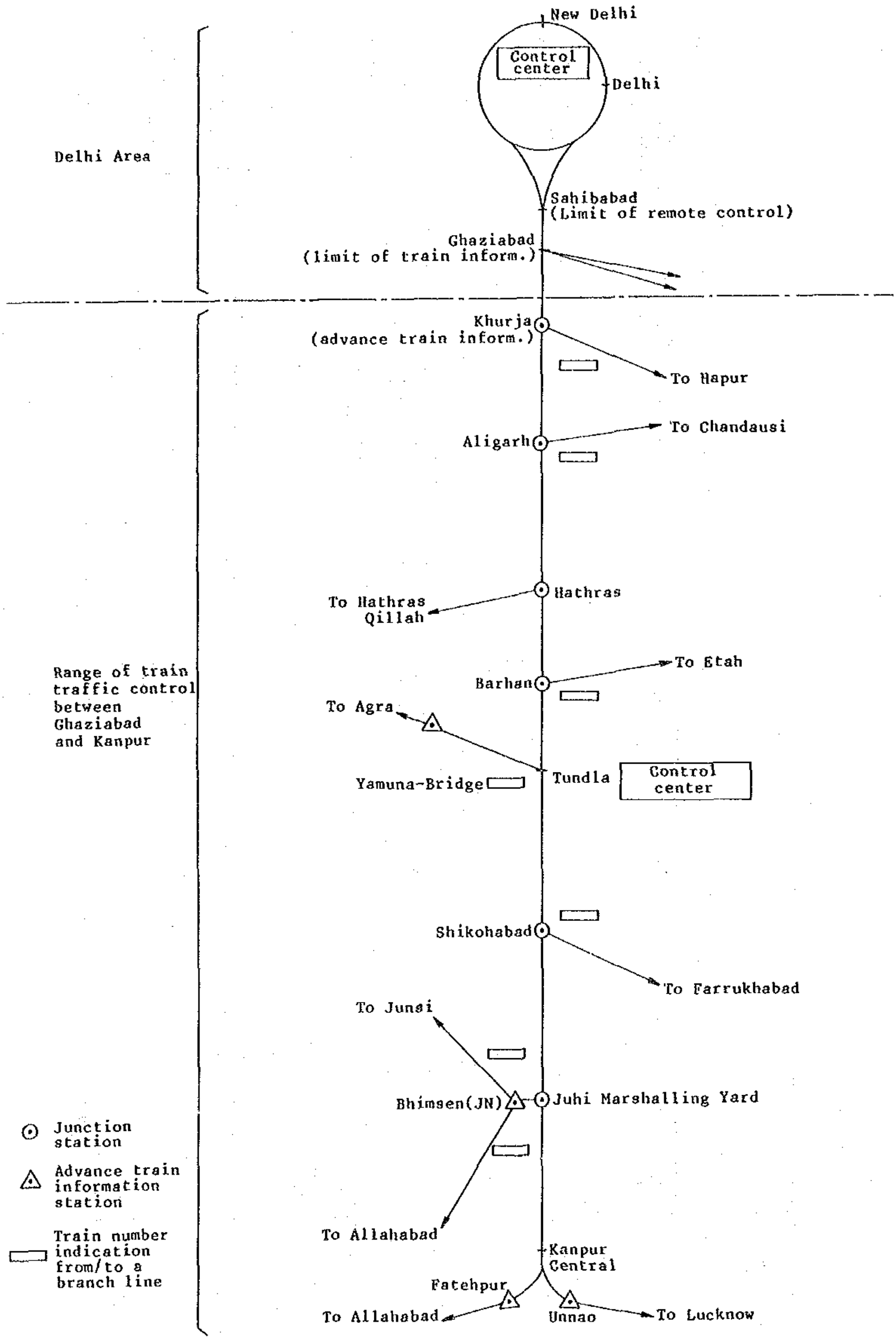


Fig. 4.4.2-13 Range of Train Traffic Control

(7) Telecommunication equipment

1) Telecommunication circuit

As for the short distance circuit, aluminum sheathed cable of the screening factor of 0.1 is installed underground along the railside. The circuit consists of 14 quads, whose channels are used for traffic control telephone, block circuit, wayside telephone, sub-station control circuit, etc.

For the long distance circuit, a 120 ch microwave link is used for telephone trunk line, teleprinter, direct telephone, etc.

In view of the fact that nearly full capacity of the above two circuits is occupied, it is thought necessary to drastically increase the circuit capacity to cope with the future increase in information volume due to train traffic increase and modernization of railway system.

Based on the above consideration, IR is planning a nationwide upgrading of telecommunication system based on a digital microwave network of max. 960 ch.

Hence, this Project will be planned with the assumption that the related telecommunication networks will be upgraded by the aforementioned separate project.

2) Train radio

Along with the increase in number and speed of trains, the necessity of train radio as a direct communication media between dispatchers and train drivers will increase to improve traffic control functions.

In addition, needs for on-board-passenger information will grow, for example, information regarding train delay, connection of trains and emergency. Therefore, other direct communication media between station masters and guards will also be required.

From such a viewpoint, it is desirable to introduce the train radio as soon as possible.

For reference, outline of the various train radio systems used by Japan Railways (JR) are shown in Appendix 5-7.

4-4-3 Electrification

(1) Power source and substation

The increased track capacity may allow trains to operate at shorter headways; the speed-up of trains up to 160 km/h will raise the powered running rate, and require the operation of a double-header, a train pulled by two electric locomotives. These two factors will result in an increase in load current.

In this case the following three salient points should be taken into account:

- The transformer capacity of substation
- The current capacity of OHE
- The minimum feeding voltage at the end of a feeding zone

If the future load increase is expected to be less than 150% of the present value, various measures can be taken to solve the above problems; for example, to install additional transformers for parallel operation, to provide feeder wires, or to insert series capacitors on the secondary side of the transformers and/or in the feeding circuit.

However, these measures will be insufficient to cope with the sharp traffic increase in 2000, when the load will reach about 2.5 times of the current value.

Therefore, studies have been made on two improvement plans for 1) addition of 6 more substations, and 2) conversion from the existing feeding system into AT feeding system as drastic improvement measures; and also on introduction of thyristorised thyristor control reactor (TCR) as a provisional measure until the time when these drastic improvement measures are to be taken.

1) Basic principle

In preparing the improvement plans, the followings are taken into consideration:

- Provide a system well coordinated with the existing one.
- Make a system most economically, with maximum use of domestic products.
- Introduce new technology for the upgrading.
- Solve the current problems concerning the existing installations prior to the execution of this Project; make efforts to work out the remaining problems, if any, while the Project is in progress.

The most serious current problem is frequent trippings of feeder circuit breakers. Without solving this problem, it is feared that the purpose of the Project will not be achieved since the frequent trippings will result in chronic traffic disorder even after improvement in track capacity and train speed. Appendix 6-1 describes this problem and countermeasures proposed.

2) Alternative 1: Addition of 6 substations

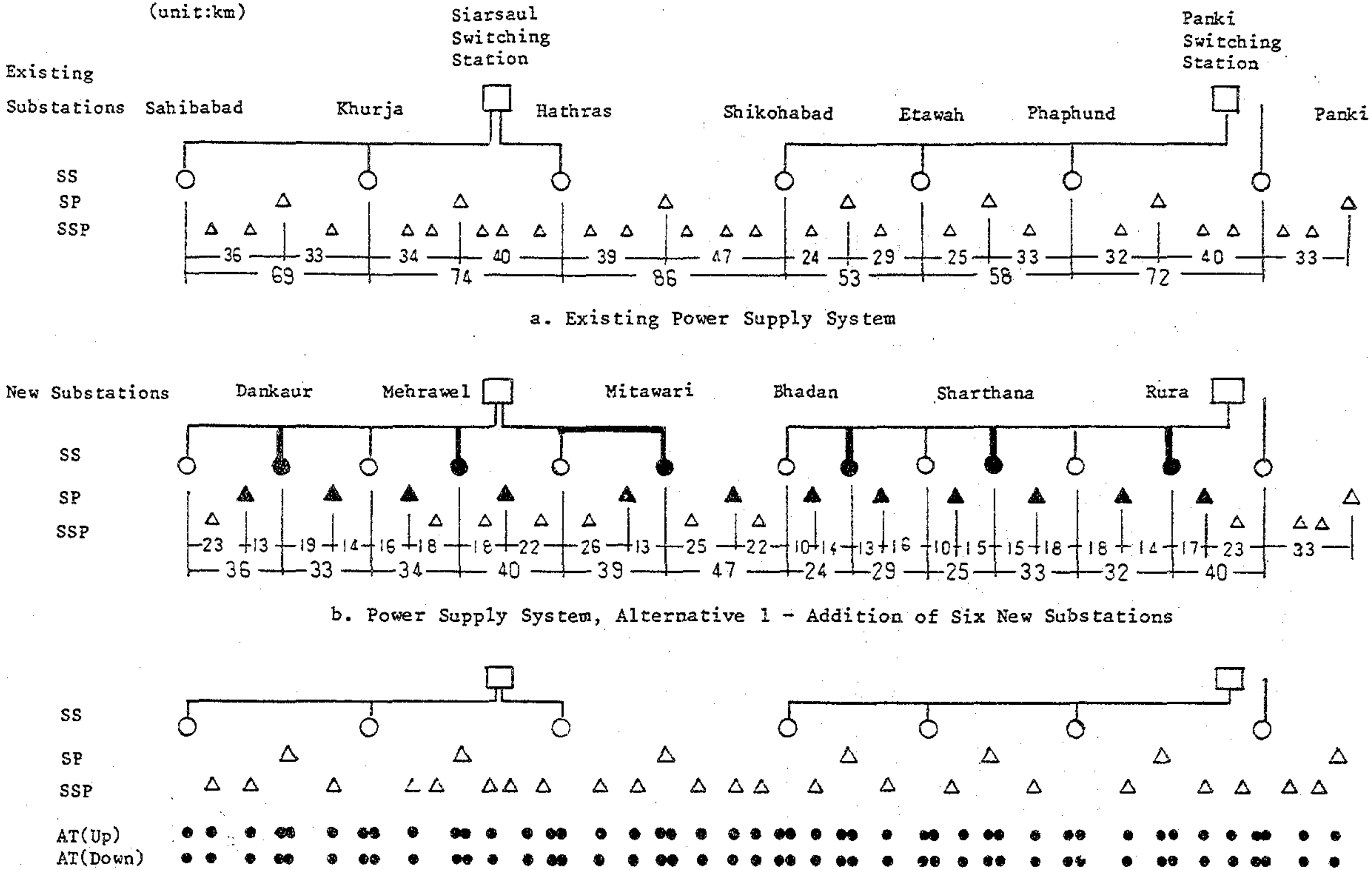
a) System configuration

As illustrated in Fig. 4.4.3-1 a. and b., six additional substations will be provided inbetween existing substations (SSs). The sectioning posts (SPs) inbetween the existing substations will be converted into SSs. If a new SS is constructed in the area adjacent to the existing SP, the existing interrupters of SP can be utilized as they are.

The Alternative 1 will not change the existing feeding system and thus may allow the existing installations to be used to the fullest extent.

The power will be provided for five of the six new substations from the 132 kV power transmission line of IR. This power transmission line will be extended by about 40 km from the Hathras substation to feed the new Mitawali substation.

This alternative plan is under way by IR, and 6 substations are scheduled to be constructed by 1990. Hence, major items of this plan are described as follows:



a. Existing Power Supply System

b. Power Supply System, Alternative 1 - Addition of Six New Substations

c. Power Supply System, Alternative 2 - Conversion to AT Feeding System

Fig. 4.4.3-1 Existing and Proposed Power Supply Systems

b) Substation

Transformer: 12.5 MVA, 2 banks

Connection of principle circuits and layout: IR's standard system

Circuit breaker: Gas CB, 72 kV, 600 A

Improvement items:

- Introduce the high-speed, automatic circuit reclosing system for feeder circuit breakers
- Convert the current distance relay into a static relay having the characteristic of parallelogram
- Introduce a fault locator of reactance measuring type
- Introduce an automatic, sequential closing method for interrupters

(See Appendix 6-1.)

c) Sectioning post (SP)

In adding 6 substations, the existing 12 subsectioning posts (SSPs) are converted into sectioning posts (SPs).

d) Substation remote control system

The conventional supervisory remote control systems at remote control center (RCC) of Tundla and Allahabad are to be replaced with a new microprocessor-based system, the type now in use in Agra RCC, by 1989.

For reference, Appendix 6-2 outlines the modern substation supervisory remote control system, that JR has recently developed and put to use.

3) Alternative 2, Converting the existing system into AT feeding system

a) System composition

Alternative 2 aims to strengthen the power supply capacity by converting the existing feeding system into AT feeding system. Fig. 4.4.3-1 c. shows the configuration of the converted AT feeding system.

b) Main features

This alternative has the following features:

- The number of substations will be the same as it is. However, since the major equipment such as transformers, circuit breakers, and disconnecting switches and connection of principle circuits for AT feeding substations are different from those for the existing substations, full-scale renewal must be made for all the existing substations.
- The power capacity of an AT substation must be approximately two times as large as that of an existing substation.
- The main equipment of the existing sectioning posts and subsectioning posts have to be converted from the single pole type to the double pole type.
- It is necessary to provide each of the up and down lines with a 25 kV insulating feeder wire over the entire line.

The schematic diagrams of substation, sectioning post and subsectioning post for AT feeding system are shown in the Appendix 6-3.

4) Economic comparison of the two alternatives

With rough estimation, Alternative 2 requires the investment three times as much as that for Alternative 1. The reason is the latter can utilize the 7 existing substations and 12 of the 22 existing subsectioning posts as they are, whereas the former requires a drastic modification or improvement as described in 3) b).

Therefore, it is most appropriate to select Alternative 1, i.e. Addition of 6 Substations.

5) Study on introduction of thyristor control reactor (TCR)

A study have been made on TCR, shunt capacitor and thyristor-controlled shunt reactor provided at the end of feeding zone.

The purpose of this study is to examine the effect of TCR and see the feasibility of applying it as a provisional measure until the 6 substations are to be added on the Section. Appendix 6-6 gives the study result.

The result discloses that TCR is effective in improving the power factor and reducing the voltage drop, but it is considered not practical to use it because its power loss is extremely large and its cost is much higher than a substation.

It is more economical to install shunt capacitor equipment at substation to improve the power factor and also provide series capacitors for substation transformer and feeding circuit to reduce the voltage drop. (See Appendices 6-3 and 6-4.)

6) Improvement measures to solve current problems

As for measures to solve the frequent trippings of substation circuit breakers, refer to Appendix 6-1.

a) Choose 2 or 3 sections where the tripping frequency is high.

b) Introduce the automatic circuit reclosing system to the feeder circuit breakers on the aforementioned sections; on condition that these breakers can withstand the duty of "0-0.5 sec-CO".

   If the results are good, introduce this method over the entire section.

c) Introduce and try other measures described in Appendix 6-1, starting from the most applicable one.

(2) Overhead equipment

1) Outline

The overhead equipment (OHE) on the Delhi-Kanpur section is under the 25 kV simple feeding system, with booster transformers installed in the urban area.

The catenary wire is of cadmium copper, stranded wire, 65 mm2; it has an anticreeper in the middle of the tension length, with an autotensioning device provided at both ends; and the contact wire is a hard drawn copper, grooved wire, 107 mm2. The OHE system is of simple polygonal type, having presag.

There are three types of neutral sections: overlap, section insulator, and PTFE.

Table 4.4.3-1 shows the salient features as described above.

Table 4.4.3-1 Features of OHE System, IR

Item	Section	
	Kanpur-Tundla	Tundla-Delhi
Type of catenary system	Simple polygonal	Simple polygonal
Size of catenary wire	65 mm^2, cadmium copper	65 mm^2, cadmium copper
Size of contact wire	107 mm^2, hard drawn copper	107 mm^2, hard drawn copper
Tension length	1,500 m	1,500 m
Regulated or unregulated	Regulated	Regulated
Maximum span length	72 m	63 m
Stagger	$\pm$20 cm on tangent track	$\pm$20 cm on tangent track
Height of contact wire	5.60 m	5.70 m
Presag	100 mm	90 mm
Section insulator on main line	PTFE type	PTFE type
Current carrying capacity capacity	600 Amps	600 Amps

2) Problems caused by the speed-up of the trains

Fig. 4.4.3-2 shows the problems, causes, and countermeasures that will arise from the speed-up of trains.

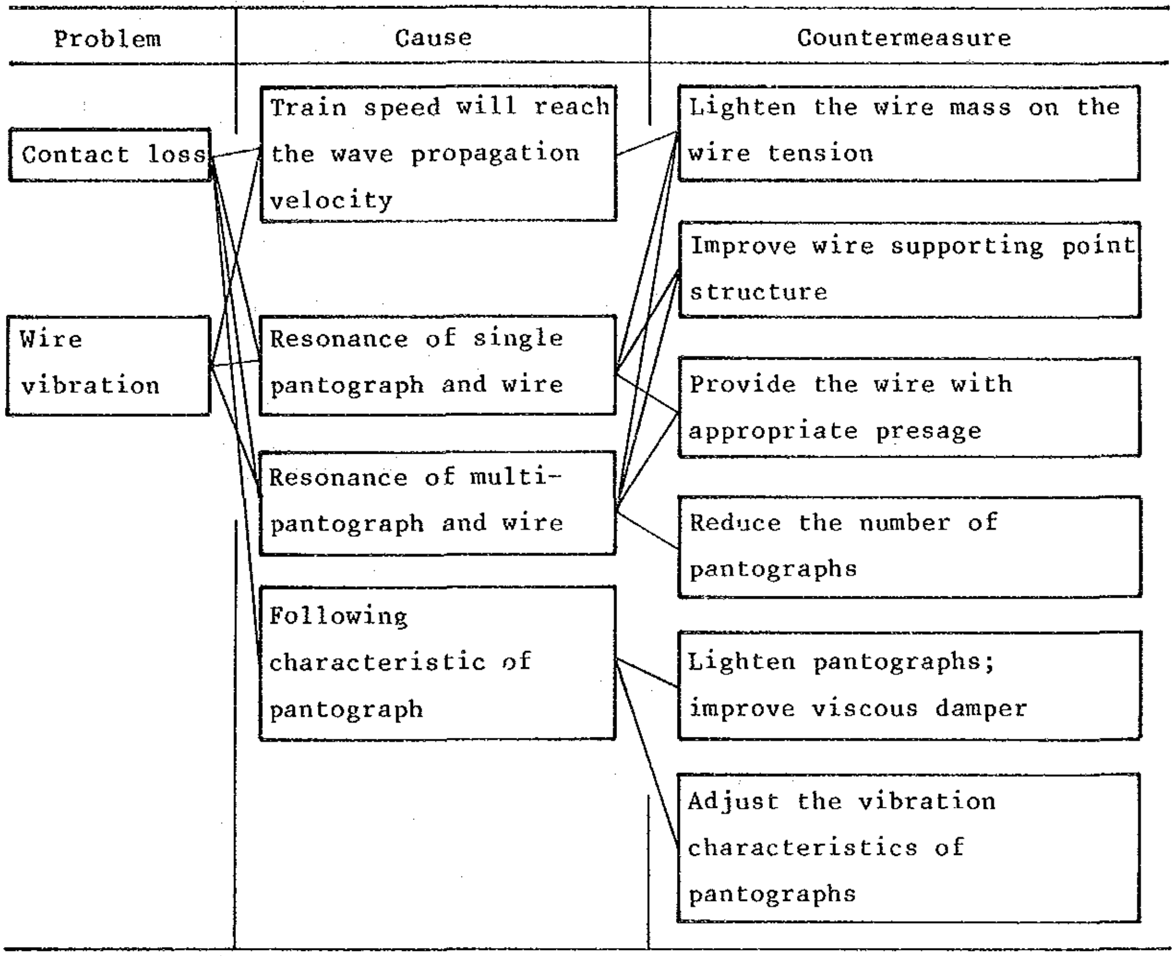


Fig. 4.4.3-2 Problems, Causes, and Countermeasures Caused by the Speed-up of Trains

- The more the contact loss, the worse will be the pantograph strips and contact wire and their service lives will be shortened.
- The increase in wire vibration will result in contact loss, and also in the deterioration of fittings.

3) Features of the existing OHE

Table 4.4.3-2 shows the estimated wave propagation velocity of OHE, spring constant of contact wire, amplitude of variation of spring constant and resonance velocity on the simple polygonal type OHE, currently used in IR. (See Fig. 4.4.3-3.)

The Supplemental explanations on the above characteristics are described in Appendix 6-9.

Table 4.4.3-2 Estimated Features of the Existing OHE System, IR

Item	Section	
	Kanpur-Tundla	Tundla-Delhi
Catenary wire - Kind of wire - Tension	 Cd Cu 65 mm^2 1,000 kgf	 Cd Cu 65 mm^2 1,000 kgf
Contact wire - Kind of wire - Tension	 Cu 107 mm^2 1,000 kgf	 Cu 107 mm^2 1,000 kgf
Maximum span length	72 m	63 m
Wave propagation velocity	400 km/h	400 km/h
Spring constant - Maximum - Minimum - Average Variation ratio of spring constant	 4,500 (N/m) 1,100 (N/m) 2,800 (N/m) 0.61	 4,500 (N/m) 1,200 (N/m) 2,850 (N/m) 0.57
Theoretical resonance velocity	159 km/h	157 km/h
Natural vibration	0.77 Hz	0.88 Hz

Note: The equivalent mass of AM-12 type pantograph is taken as 32 kg

Supposing train operation at 160 km/h with this system, the followings are assumed:

- The difference between the wave propagation velocity and the train speed is so large that the train is allowed to operate at 160 km/h.
- The resonance velocity and the maximum train speed become almost the same value, therefore the vibration of pantograph may increase causing a large contact loss.
- The higher the train speed, the more the pantograph will lift up the contact wire, and it might hit the steady arm.

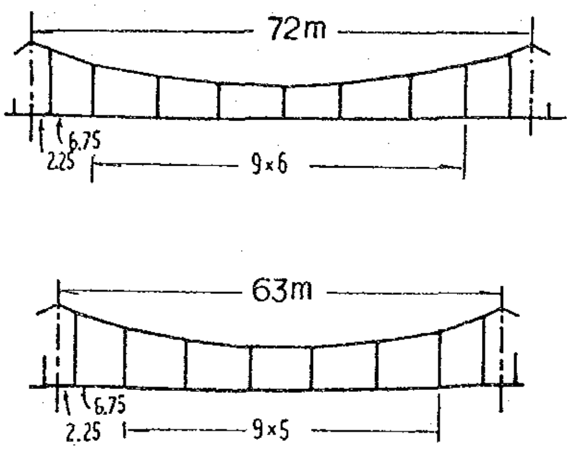


Fig. 4.4.3-3 OHE Wire System of Simple Polygonal Type

4) Improvement of OHE

a) Basic principle

In order to collect current without big contact loss at high speed train operation, it is necessary to maintain uniform spring constant of the OHE wire over the span. It may be more effective to provide it with presag to make flat the locus of pantograph.

However, overabundant presag and steep gradient must be avoided, since this may lead to contact loss. Resonance between OHE wires and pantograph attributable to the following characteristic of pantograph must also be avoided.

Improvements, based on the measures shown in Fig. 4.4.3-2, will be made by

- Raising the resonance velocity of the OHE system than the maximum train speed.
- Suppressing the effect of the resonance as much as possible even if it might arise.

As for the former measure, the following measures may be taken such as: i) To increase the tension of catenary and/or contact wires; ii) To use light material for OHE wires; and iii) To improve the supporting point structure to realize the uniform spring constant.

In respect to latter measure, it is also effective to increase OHE wires' tension, provide the pantograph with damper, and to lighten the pantograph.

On the Delhi-Kanpur section, types and speeds of train are diverse, with the maximum speed of 160 km/h. Therefore, should the resonance velocity be hightened to more than 160 km/h, it would be possible for all trains to collect current without trouble.

To increase the resonance velocity, the following measures are considered from the formula (B).

(See Appendix 6-9)

i) Decrease the equivalent mass of the pantograph and OHE system.

ii) Lessen the variation ratio of spring constant of OHE system.

iii) Increase the average spring constant of OHE system.

iv) Enlarge the span length.

In this Project, such measures as change in the span length, replacement of the current OHE wires and the use of light pantograph will not be taken to minimize the investment, therefore, improvement is to be planned based on ii) and iii).

b) Improvement

Alternative improvement plans considered call for:

- Lightening the mass of OHE wires: a) increase in the catenary wire tension and b) increase in the tension of the catenary and contact wires.
- Improving the wire supporting point structure: convert in to the stitched simple catenary system.
- Providing the catenary system with presag: regulate the presage to the most appropriate value.

In addition, to cope with the increase in the uplift of contact wire due to the train-speed increase, it is necessary to widen the space between the register arm of the bracket and the contact wire and also to replace the steady arm with a new type suitable for high-speed train operation, which are already under studying in IR.

For alternative OHE improvement plans, their estimated characteristics are shown in Table 4.4.3-3.

Table 4.4.3-3 Estimated Characteristics of Alternative OHE Systems

Item \ Section	Kanpur - Tundla				Tundla - Delhi			
Conditions of Equipment								
Catenary wire								
- Kind of wire	Cd Cu 65 mm^2				Cd Cu 65 mm^2			
- Tension (kgf)	1200	1200	1000	1200	1200	1200	1000	1200
Contact wire								
- Kind of wire	Cu 107 mm^2				Cu 107 mm^2			
- Tension (kgf)	1000	1200	1000	1200	1000	1200	1000	1200
Switched wire								
- Kind of wire	-	-	Cd Cu 24mm^2		-	-	Cd Cu 24mm^2	
- Tension (kgf)	-	-	150	200	-	-	150	200
- Length (m)	-	-	12	12	-	-	12	12
Maximum span length (m)	72 m				63 m			
Estimated Characteristics								
Spring constant								
- Maximum (N/m)	4900	5400	1600	1900	4900	5400	1600	1900
- Minimum (N/m)	1200	1300	1100	1300	1400	1500	1200	1500
- Average (N/m)	3050	3350	1350	1600	3150	3450	1400	1700
- Vibration ratio of spring constant	0.61	0.61	0.19	0.19	0.56	0.57	0.12	0.12
Theoretical resonance velocity (km/h)	167	175	158	173	165	172	152	167
Natural vibration (Hz)	0.80	0.84	0.76	0.84	0.92	0.96	0.87	0.96
Wave propagation velocity (km/h)	420	440	400	430	420	440	400	440

By means of increasing the tension of the both existing catenary and contact wires from 1,000 kg to 1,200 kg, the resonance velocity will become 170 km/h or more without improving the OHE wire supporting point structure, enabling train operation at 160 km/h without problem.

However, it is advisable that in addition to the theoretical studies the stability of the contact force between the contact wire and the pantograph and the contact loss ratio will be verified by field tests or by computer-aided simulations.

(3) Computer Simulation

The motion of the OHE system brought about from the running of pantograph at the speed of 160 km/h has been analized by computer simulation, and the result of which is outlined as below. For details, see Appendix 6-12.

1) Simulation on the existing OHE system

Simulation results on the existing OHE system are as given in Table 4.4.3-4.

Table 4.4.3-4 Simulation Results on the Existing OHE System

Item / Span length (m)	Contact loss ratio (%)	Uplift at support point (mm)	Max. uplift (mm)
63	2.1	55	120
72	1.2	50	141

Considering the fact that in JR the allowable contact loss ratio is 3% and the allowable uplift of steady arm is 100 mm, it is theoretically possible for running at the speed of 160 km/h even with the existing OHE system. However, it should be noted that this simulation has been made where there are no influence of wind pressure, no contact wire gradient, and the state of the contact wire is flat.

From out experiences, the uplift at the support point, when actual cars are running, it to become 1.5 to 2 times the value calculated by computer simulation. The reasons for this are the increase in uplift force by the wind from the head car and the contact wire gradient. Therefore, taking into account the uplift at the support point to become about 110 mm (2 x 55 mm), it is necessary to keep a certain gap between pantograph and steady arm so that they may not touch each other.

The contact loss under this simulation is merely due to the vibration between pantograph and catenary system, but under the actual train operation, in addition to the foregoing vibration, contact loss will occur due to the hard spots of steady arm/fittings and the contact wire gradient. Therefore, the contact loss in actual running is considered larger than that by simulation.

2) Simulation on the upgraded OHE system

Simulation results on the upgraded OHE system are as given in Table 4.4.3-5.

Table 4.4.3-5 Simulation Results on the Upgraded OHE System

Item / Span length (m)	Contact loss ratio (%)	Uplift at the support point (mm)	Maximum uplift, (mm)
63	1.9	42	95
72	0.5	37	114

Compare the uplifts shown in Tables 4.4.3-4 and 4.4.3-5. The uplift on the upgraded OHE system is about 20% smaller than that on the existing OHE system, and contact loss ratio is also smaller.

Table 4.4.3-6 shows the comparison of pantograph vibration amplitudes and contact forces between the existing OHE system and the upgraded OHE system.

Table 4.4.3-6 Comparison of Pntograph Vibration Amplitude and Contact Forces between the Existing OHE System and the Upgraded OHE System (at 160 km/h).

Span length 63 m, presag 90 mm

	Standard deviation of pantograph vibration amplitude (mm)	Standard deviation of pantograph contact force. (N)	Pantograph contact force	
			Maximum. (N)	Minimum. (N)
Existing catenary system, 1,000kgfX 2	25	31	212	72
Upgraded catenary system, 1,200kgf X 2	19	27	184	75

Span length 72 m, presag 100 mm

Existing catenary system, 1,000kgfX 2	28	31	205	76
Upgraded catenary system, 1,200kgfX 2	19	26	192	78

The smaller the standard deviation of pantograph vibration amplitude and contact force, the milder the inertial action of pantograph and the better the current collection characteristic.

And the closer the pantograph contact force to the dynamic uplift force of pantograph (114 N at the speed of 160 km/h), the better the current collection characteristics. Therefore, it may be said that the characteristics of the upgraded OHE system where the tension of both catenary and contact wires are increased up to 1,200 kg, is superior in every respect to the existing OHE system.

3) Simulation on the two-pantograph operation

It is planned that 160 km/h trains are to be pulled by two electric locomotives.

Computer simulation has been made on the motion between pantograph and catenary system with tension of 1,200 kg when two pantographs are running at the speed of 160 km/h.

Fig. 4.4.3-4 shows the distance between pantographs.

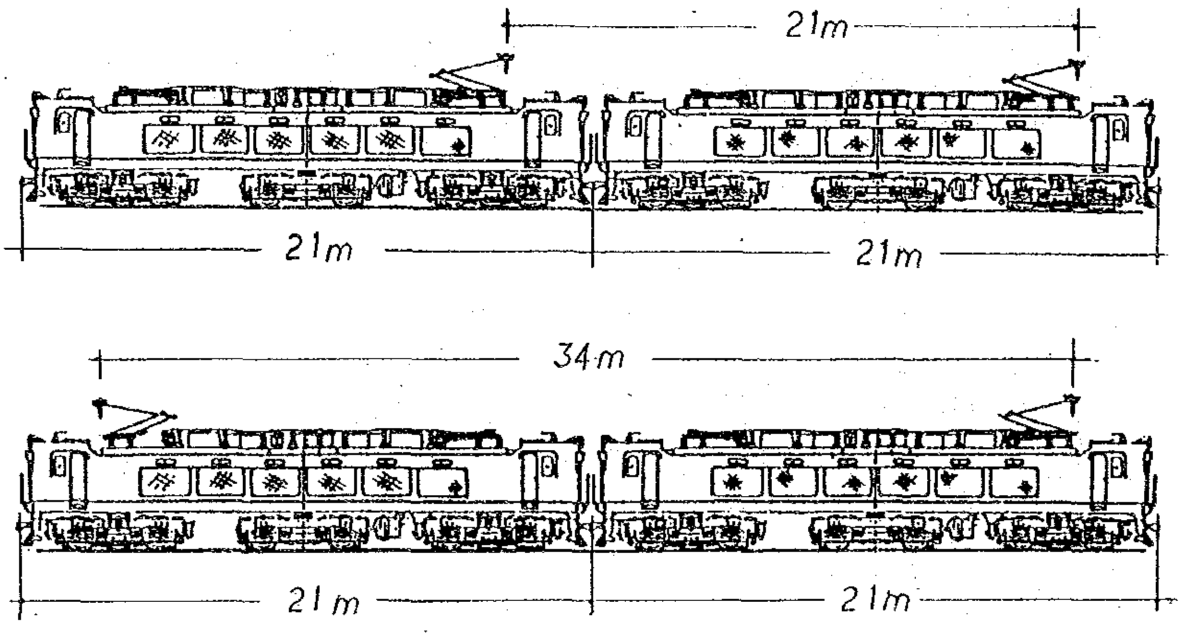
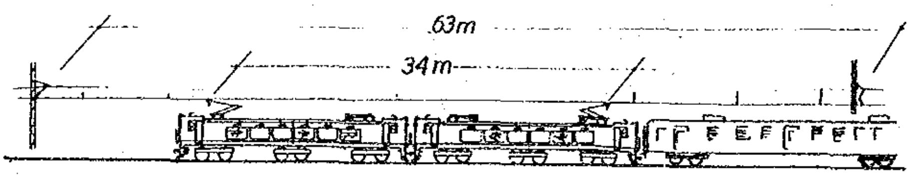


Fig. 4.4.3-4 Distance between Pantographs of Two Electric Locomotives

In both cases, as shown in Fig. 4.4.3-4, there might be a chance for the two pantographs to run simultaneously in a 63 m span. This means that the rear pantograph will run the contact wire section where vibration brought about by the front pantograph is remaining.



Computer simulation has been made on the following 8 combination cases:

Case	Distance between pantographs (m)	Span length (m)	Presag (mm)
a	21	63	90
b			50
c		72	100
d			60
e	34	63	90
f			50
g		72	100
h			60

Tension of catenary and contact wires are 1,200 kg, and both wires are provided with about 0.8/1,000 presag that is 50 mm and 60 mm pre-sag for 63 m and 72 m span length respectively.

Table 4.4.3-7 shows the result of the simulation.

Table 4.4.3-7 Simulation Results on the OHE Characteristics at Two-pantograph Operation 160 km/h

Item / Case	No of Panto	Contact loss ratio (%)	Uplift at the support point (mm)	Maximum uplift (mm)	Standard deviation of pantograph vibration amplitude (mm)	Standard deviation of pantograph contact force (mm)	Pantograph contact force (N)		Distance between panto (m)	Span length (m)	Presag (mm)
							Maximum	Minimum			
a	1	1.8	70	148	34	36	258	73	21	63	90
	2	2.6			15	34	185	55			
b	1	1.6	71	143	32	42	288	59			50
	2	2.6			41	44	197	31			
c	1	0.0	64	188	39	34	243	71		72	100
	2	2.0			25	37	199	24			
d	1	0.2	62	207	42	40	248	41			60
	2	2.4			48	42	216	9			
e	1	1.8	62	104	21	28	187	72	34	63	90
	2	1.8			17	26	169	70			
f	1	1.8	48	110	18	24	191	80			50
	2	2.2			15	20	160	80			
g	1	0.2	60	141	24	26	207	75		72	100
	2	0.9			16	25	171	67			
h	1	0.0	54	152	22	24	189	80			60
	2	1.0			25	23	167	73			

According to Table 4.4.3-7, when two pantographs run through the upgraded OHE system.

- the contact loss is not remarkably large,
- the uplift at the support point and the maximum uplift are larger than those at one pantograph operation, and
- the standard deviation of pantograph vibration amplitude and contact force is larger than that at one pantograph operation.

When the 21 m and 34 m distances between pantographs are compared, each of the followings is larger in the former case.

- the contact loss of the rear pantograph,
- the uplift at the support point, and
- the standard deviation of pantograph vibration amplitude and contact force.

As can be seen from the foregoing, the current collection characteristic in the case of the 34 m is better than that of the 21 m distance.

The OHE system with about 0.8/1,000 presag does not show the smaller contact loss compared with the existing presag, but is more effective in suppressing the uplift at the support point.

(4) Simulation result

Characteristics of both the existing and the upgraded OHE systems have been so far described, coupled with the simulation of the two pantographs operation by the upgraded OHE system.

General trend is that the faster the speed, the more the contact loss and uplift on any OHE system. For contact loss, refer to Appendix 6-14. Fig. 4.4.3-5 shows the simulation result on the contact loss at the speed of 160 km/h and uplift at the support point.

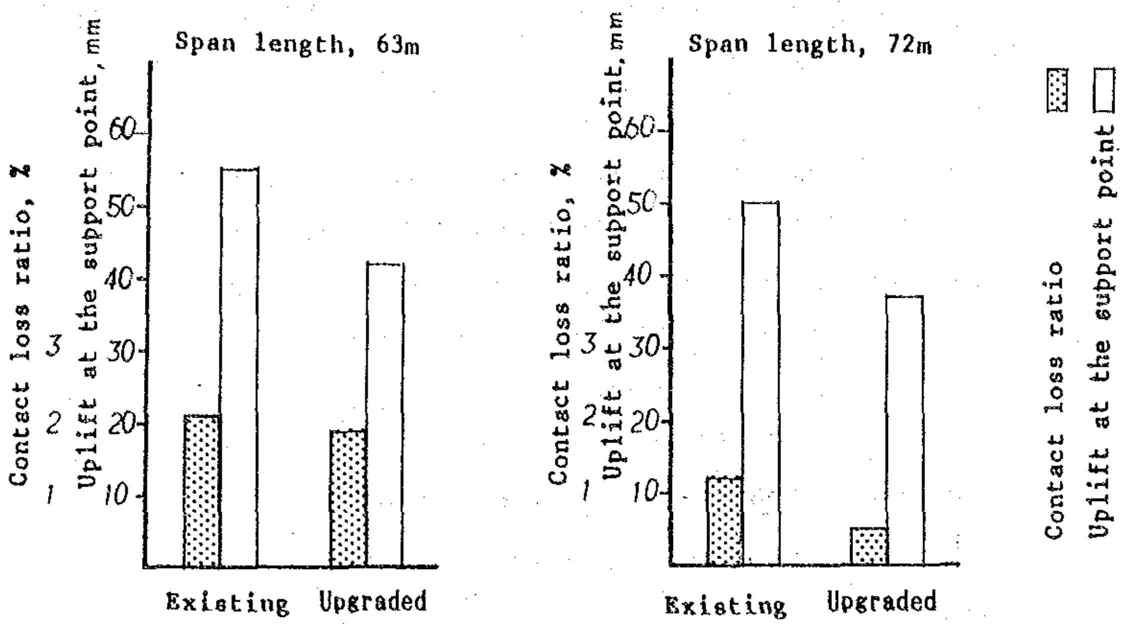


Fig. 4.4.3-5 Characteristics of Existing and Upgraded OHE Systems (One pantograph, 160 km/h)

This result shows that in both span length cases, the upgraded OHE system with increased tension shows better characteristics in contact loss and support point uplift than the existing one.

The simulation conducted also discloses that the higher the tension, the faster the wave propagation velocity (see Tables 4.4.3-2, and 4.4.3-3) and the larger the average spring constant value (Appendix 6-9, 3), thus improving current collection characteristics.

Fig. 4.4.3-6 shows the simulation results, on the said characteristics for different span length and presag when two pantographs are operated.

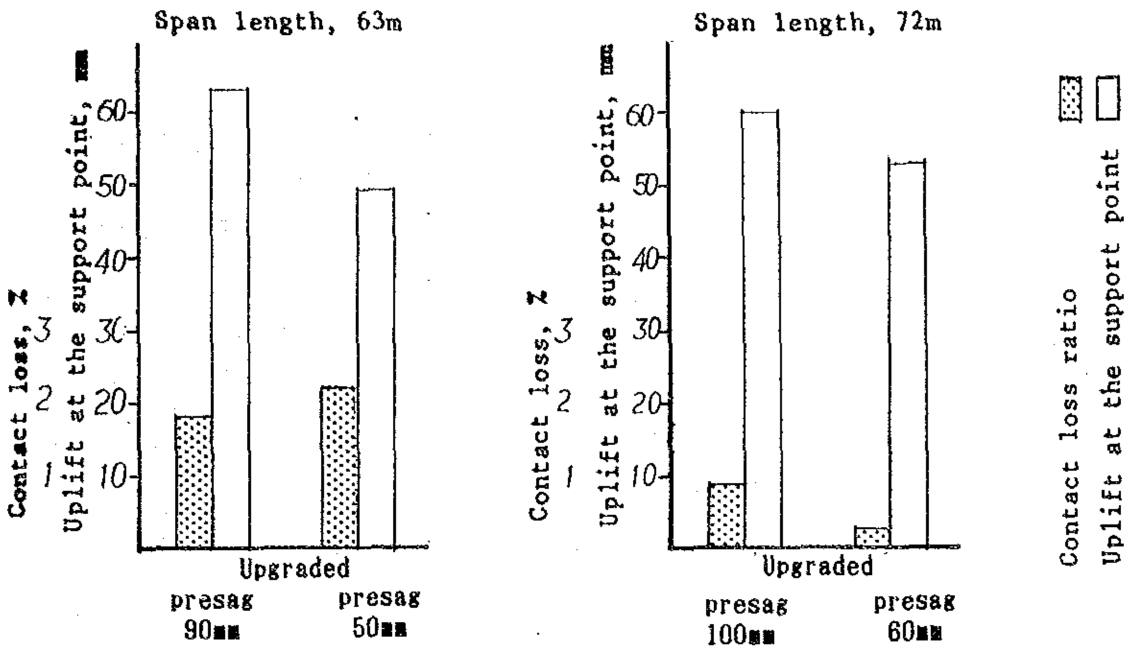


Fig. 4.4.3-6 Characteristics of OHE Systems, Existing and Upgraded presag, 1200 kgf (Two pantographs, 160 km/h)

In both span length cases, the contact wire with 0.8/1000 presag shows smaller uplift than that with presag of 1.4/1000; however, in the 63 m span length cases, the contact loss ratio is larger by 20% compared with the 0.8/1000 presag.

Meanwhile, it is generally said that the contact wire with presag of 1/1000 - 0.8/1000 will show the best current collection, characteristics.

The presag currently applied in IR (100 mm in. the 72 m span, and 90 mm in the 63 m span) is approximately 1.4/1000.

Judging from the aforementioned factors, it would be better to reduce the existing presag to 0.8/1000-1/1000. Besides, there remains a current collection problem on the special section. Firstly, on the overlap section, it is necessary to adjust the height of contact wire so that the pantograph may move smoothly. Secondly, contact wire gradient.

In this regard, IR's Manual of AC Traction Maintenance and Operation, Overhead Equipment Layout Plans, provide that contact wire gradient shall be 3 mm/m or less. But it is considered necessary to modify this to be 1 mm/m (1/1000) or less for high-speed current collection, as in practice on JR's Shinkansen.

As a conclusion of the study, for 160 km/h high-speed operation, it is recommended to improve the existing OHE system, as follows:

1) Increase the tension of catenary wire and contact wire from the present 1000 kgf to 1200 kgf.

2) Reduce the present presag smaller to 1/1000 - 0.8/1000.

3) Widen the allowance between bracket register arm and contact wire to 200 - 250 mm.

4) Reduce the present contact wire gradient smaller to 1/1000 or less.

In addition, prior to commencement of the commercial operation, it is necessary to conduct actual train running test and fully identify the current collection characteristics and related technical aspects.

4-5 Training

The improvement of the section between Ghaziabad and Kanpur will allow 160 km/h high-speed train operation and permit an increase in doubled train number. To maintain it satisfactorily, various types of testing and training will be required before the commencement of the commercial operation. Regarding track, OHE, signalling, and rolling stock, 160 km/h running tests should be executed in connection with their maintenance. In particular, as for electronics technology thorough training on their maintenance method should be made as described below.

(1) School Training

For bringing up maintenance crews for electronics equipment, collective training by use of practice facilities should be provided at a training school by the following three courses:

a) Advanced Course (Approx. three months)

A course to train related engineering officers and training school instructors on the new technologies and their maintenance method at a school or abroad.

b) Professional Technical Course (Approx. three months)

A course to provide foremen with the technical training on the electronics equipment. (ex. solid-state interlocking device, electronic level crossing controller, C.T.C, A.W.S, Jointless A.F. track circuit, etc.)

c) Maintenance Course (Approx. six months)

A course to train maintenance crew on the basic maintenance method

(2) On-the-job training

Those who have completed the aforementioned school training will engage in the upgrading works so that they may comprehend know-how of new technology.

4-6 Investment Plan

4-6-1 Investment Timing

The start of operation is scheduled for the outset of 1991, with the time for construction work set at 1988-1990 (see Table 4.6.3-4)

4-6-2 Premises

(1) Based on acquired data on construction materials, wages and construction system, and local conditions, the construction cost is estimated.

(2) The estimation is made as of July, 1987, and no escalation element is taken into account.

(3) Costs of imported equipment and materials are priced in CIF.

(4) The foreign exchange rate is Rs1 = ¥11.35.

(5) Domestic products, so far as available, is used to save foreign currency.

(6) Wages for all construction works is paid in local currency.

(7) Investment costs for the other projects to be implemented in the 7th 5-Year Plan are not included in the construction cost of this Project. (See Appendix 7-1)

(8) 3% reserve for contingency, and 10% general charge are appropriated in the budget.

4-6-3 Investment cost and Implementation Schedule

(1) Investment Cost

1) Initial investment

Table 4.6.3-1(a) Initial Investment Cost

(10^6Rs)

Item	Local currency	Foreign currency	Total
Track and structure	394.7		394.7
Signalling/ telecommunication	598.9	266.6	865.5
Electrification	78.3	32.5	110.8
Subtotal of ground facilities	1,071.9	299.1	1,371.0
Rolling stock 1990	1,010.5		1,010.5
Total	2,082.4	299.1	2,381.5

2) Additional investment

Table 4.6.3-1(b) Additional Investment Cost

(10^6Rs)

Item		Local currency	Foreign currency	Total
Rolling stock	1991~1994	1,089.3		1,089.3
	1995~1999	1,522.5		1,522.5
Total		2,611.8		2,611.8

3) Detailed investment cost

Table 4.6.3-2 Detailed Investment Cost for Upgrading the Section

Initial Investment

(10^6Rs)

Item	Classification	Total	Breakdown		
			Personal expenses in local currency	Other expenses in local currency	Foreign currency
Land	Price of land for laying tracks Others land prices	4.5		4.5	
Track and structure	Roadbed	37.8	12.0	25.8	
	Over road bridge, elevated bridge	5.2	1.0	4.2	
	Platform	10.4	3.1	7.3	
	Footbridge	9.5	1.9	7.6	
	Station building	30.5	8.2	22.3	
	Track	296.8	45.4	251.4	
Signalling/ telecommunication	Level crossing facilities	181.3	59.2	120.9	1.2
	Signalling equipment	330.3	66.5	103.5	160.3
	Telecommunication equipment	2.6	0.3	1.7	0.6
	Signalling cable	120.8	45.7	75.1	
	Telecommunication cable	2.3	1.2	1.1	
	Track circuit	228.2	43.0	80.7	104.5
Electrification	Substation equipment	35.1	2.6		32.5
	Over head equipment	74.7	38.5	36.2	
	Power distribution	1.0	0.4	0.6	
Ground facilities - subtotal		1,371.0	329.0	742.9	299.1
Rolling stock	Electric locomotive	507.2		507.2	
	Coach	145.8		145.8	
	Wagon	357.5		357.5	
	Electric car				
Rolling stock - subtotal		1,010.5		1,010.5	
Total		2,381.5	329.0	1,753.4	299.1

Additional investment (1991 ∿ 1999)

(10^6Rs)

Item	Classification	Total	Breakdown		
			Personal expenses in local currency	Other expenses in local currency	Foreign currency
Rolling stock	Electric locomotive	760.4		760.4	
	Coach	1,233.9		1,233.9	
	Wagon	617.5		617.5	
	Electric car				
Total		2,611.8		2,611.8	

4) Purpose-wise breakdown of Investment cost

Table 4.6.3-3 Purpose-Wise Breakdown of Investment Cost for Upgrading the Section

(10^6Rs)

Item	Contents	Purpose		
		Track capacity	160 km/h operation	Speed restriction
Track	Kanpur Station (1 platform, 2 lines)	33.4		
	Etawah Station (Construction of run-through line)		48.7	
	Aligrah Station (Construction of run-through line)		32.9	
	Tundla Station (Improvement of yard)			72.2
	Panki Station (Freight arrival departure line improvement)	18.8		
	Ghaziabad Station (Freight arrival departure line improvement)	39.0		
	Juhi M. Yard (Freight arrival departure line improvement)	50.5		
	Maintenance car retention line (12 stations)	3.4		
	Improvement of cant and transition curve, at 70 points, 17 km		2.4	
	Upgrading of turn out Conversion to 60 kg type on run-through main lines, at 333 points	12.9	93.5	
	Intermediate stations (Installation of safety fences on the platform)		0.8	
Structure	Improvement of bridges Replacement of multiple span bridges, and flyover bridges			3.4
	Establishment of protective track fence		36.4	
Signalling and tele-communication	(1) Solid-state interlocking device inter-locking device	204.7		
	(2) Auxiliary warning system (AWS)		73.9	
	(3) Train traffic information system	163.2		
	(4) Automatic block system	228.2		
	(5) Level crossing control	181.3		
	(6) Train approach alarming device		4.0	
	(7) Maintenance radio	0.7		
Electrification	Improvement of sub-station (6 sub-stations) devices	35.1		
	Increase in OHE wire tension, improvement of movable bracket		31.6	
Total		971.2	324.2	75.6

(2) Implementation Schedule

Table 4.6.3-4 Implementation Schedule (Upgrading the Section)

(10^6Rs)

			1987	1988	1989	1990
Fiscal year			1987	1988	1989	1990
Feasibility study			├─┤			
Securing budget			├─	─┤		
Ground facilities	Designing			├─	─┤	
	Manufacturing			├─	─┤	
	Con-struc-tion	Track/ structure		├─	──	─┤
		Signalling/ telecommuni-cation			├─	─┤
		Electrifi-cation			├─	─┤
Rolling stock	Designing			├─	─┤	
	Manufacturing				├─	─┤
Running test (160 km/h)						├─
Ground facilities	Local currency			69.5	509.4	493.0
	Foreign currency				149.3	149.8
	Sub total			69.5	658.7	642.8
Rolling stock (local currency)					505.3	505.2
Total				69.5	1,164.0	1,148.0

CHAPTER 5 BASIC CONSTRUCTION PLAN FOR THE NEW HIGH–SPEED CORRIDOR

CHAPTER 5 BASIC CONSTRUCTION PLAN FOR THE NEW HIGH-SPEED CORRIDOR

5-1 Basic Conditions

(1) The New Corridor is planned to enter operation in 2000.

(2) The transport plan of the New Corridor is planned based on fare levels that will cause passengers of the Section to divert to the New Corridor.

(3) In planning the rolling stock and ground facilities, up-to-date technology will be employed taking account of social, natural and industrial conditions of India.

(4) The Super Express trains of the maximum speed of 250 km/h will operate shuttling at the New Corridor terminal stations of Delhi, Agra and Kanpur.

(5) The Long distance Express (L. Express) train of the Section operated with a maximum train speed of 160 km/h will run into or out of the New Corridor at Delhi, Agra and Kanpur.

(6) The Super Express trains will be of the maximum train make-up of 6M10T or 2M16T and the L. Express trains will be hauled by two electric locomotives with the maximum make-up of 18 coaches.

(7) The maximum grade will be 5/1000 or less and the minimum radius of a curve will be 4000 meters except in the station compounds.

(8) Every crossing with conventional railway lines and roads will be of grade separation.

(9) A rolling stock workshop for the New Corridor trains will be built.

(10) For the maintenance works of the ground facilities, both up and down tracks will be blocked for 4 hours at night, and the maintenance depots will be built at certain intervals.

5-2 Route and Terminal

5-2-1 New Corridor Terminal Station

The location of terminals and the connection with the conventional line for Delhi, Agra and Kanpur are as follows.

(1) Delhi area - New Delhi Station

The New Delhi Station is thought to be the best for the New Corridor terminal, being located at the central part of the city with good connection with the conventional express trains and roads.

However it's train handling capacity is fully occupied.

Therefore, the space for the New Corridor terminal will have to be created in the station compound by such means as transfering existing wagon workshop, repair tracks and washing tracks to other places.

And considering the difficulty of acquiring land for the new line, the New Corridor shall be connected to the existing line near Tuglakabad. In this manner, this plan should be based on the prerequisite that, in the overall railway network upgrading plan for the Delhi area, acquisition of terminal space at the New Delhi Station and a track capacity increase can be assured.

(2) Agra area - New Terminal at the Bilochpura Station

In view of the inter-operation of the L. Express trains into/out of the conventional line, convenience of transit passengers, access to the city center and roads, the New Corridor Terminal in the Agra area will be located on the northern side of the Bilochpura Station.

From the Bilochpura Station, the New Corridor will pass the dense residential area through the Agra City Station until it reaches the Yamuna River. It will be connected with the conventional line at New Delhi side of the New Terminal. (Fig. 5.2.1-1)

(3) Kanpur area - New Terminal at the Govindpuri Station

Considering a possible shortage of track capacity of the conventional-line section used by the common use of it by the New Corridor trains

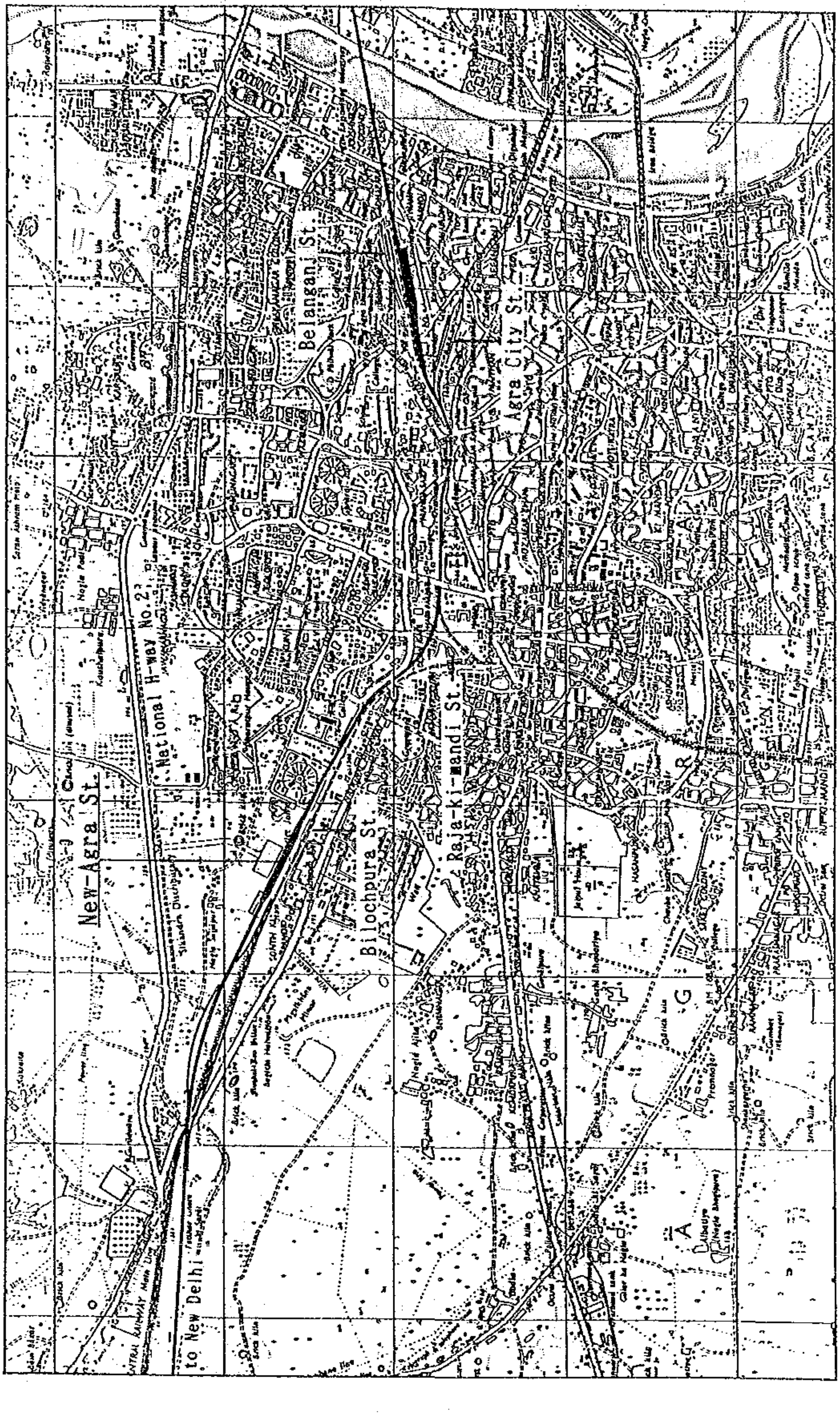


Fig. 5.2.1-1 Location of the New-Agra Station

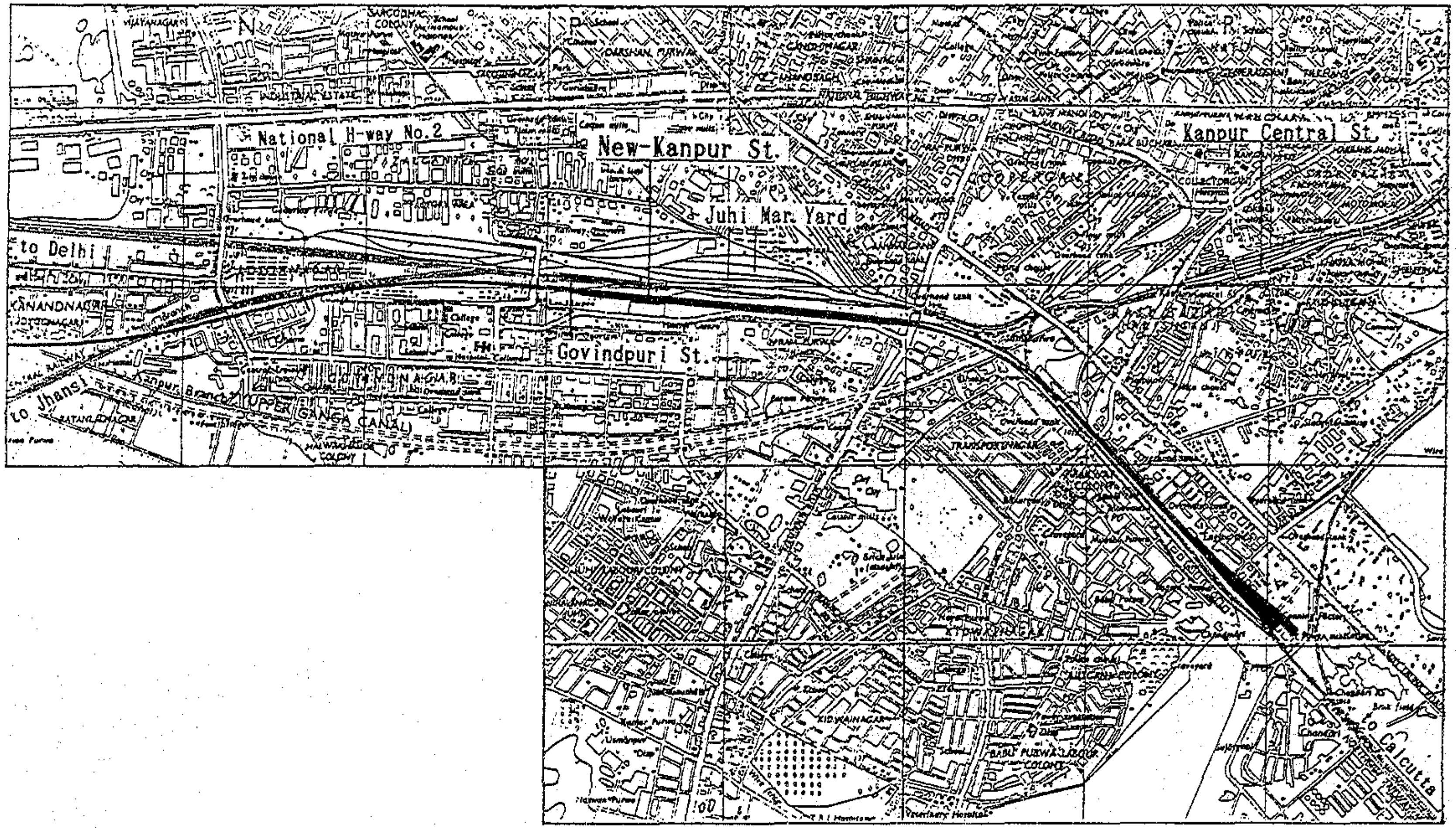


Fig. 5.2.1-2 Location of the New-Kanpur Station

and the Section train the access to the city center and roads, and convenience of transit passengers, the New Corridor terminal will be newly constructed at the southern side of the Govindpuri Station. It will be connected with the conventional line near the Kanpur SL workshop.

The terminal will be of elevated station, and nevertheless allowing no connection with the conventional Lucknow Line due to existence of a over-road bridge. (Fig. 5.2.1-2)

Comparison of the New Corridor terminals are shown in the Appendix 4-10.

5-2-2 Route

(1) Delhi - Agra (approx. 190 km)

1) Cities and geography

Ballabgarh (district capital), Palwal and Mathura (district capital) are on the right bank of the Yamuna River, and Shikandarabad, Aligarh and Hathras are on its left bank. In general, the area between these cities are flat agriculture land. On the right bank of the Yamuna River, the National Highway No. 2 runs southbound along the Bombay Line.

2) Route

Taking account of the aforementioned cities, geographical features, location of the New-Agra Terminal Station, route length, roads, railways, and the Yamuna River crossings, the route between Delhi and Agra shall be determined as follows.

The New Corridor branches off the conventional line near Tuglakabad, and comes down to the south along the Bombay Line along its western side. Near Palwal where the first intermediate station is constructed, the New Corridor runs approximately 5 km off the Bombay Line, and is located on the western side of the National Highway No. 2. About 2.5 km to the west of Hadal and Kosi, the New Corridor runs along the conventional line and goes to Mathura. In Mathura, it runs 3.5 km away from the urban area, and crosses over the Western Railway Main Line. It further proceeds, crosses over the Meter Gauge Line of the North-Eastern Railway, and heads to Agra. Near the crossing with the Western Railway in Mathura, an intermediate station is established for the convenience of transit passengers. In front of Bilochpura, where the New Corridor's Agra Terminal will be located, it crosses over the Central Railway Main Line, and reaches the New Terminal north of Bilochpura. The extension from New Delhi is 191 km, but the new line construction section is 172 km.

(2) Agra - Kanpur (approx. 260 km)

1) Cities and geography

Between these two cities are the cities of Firozabad, Shikohabad and Etawah (district capital), and Mainpuri (district capital) which is a little far from the route. Generally, the area is flat agriculture land. In north of Etawah the land between the railway and the Yamuna River is narrow and there exists eroded valleys along the river, The National Highway No. 2 runs north of the railway.

The area between Etawah and Kanpur is agricultural area with the National Highway and the Yamuna River away from the main line.

2) Route

Taking account of the aforementioned cities, geographical features, location of the intermediate stations, and the crossing of the Yamuna River, the route between Agra and Kampur shall be determined as follows.

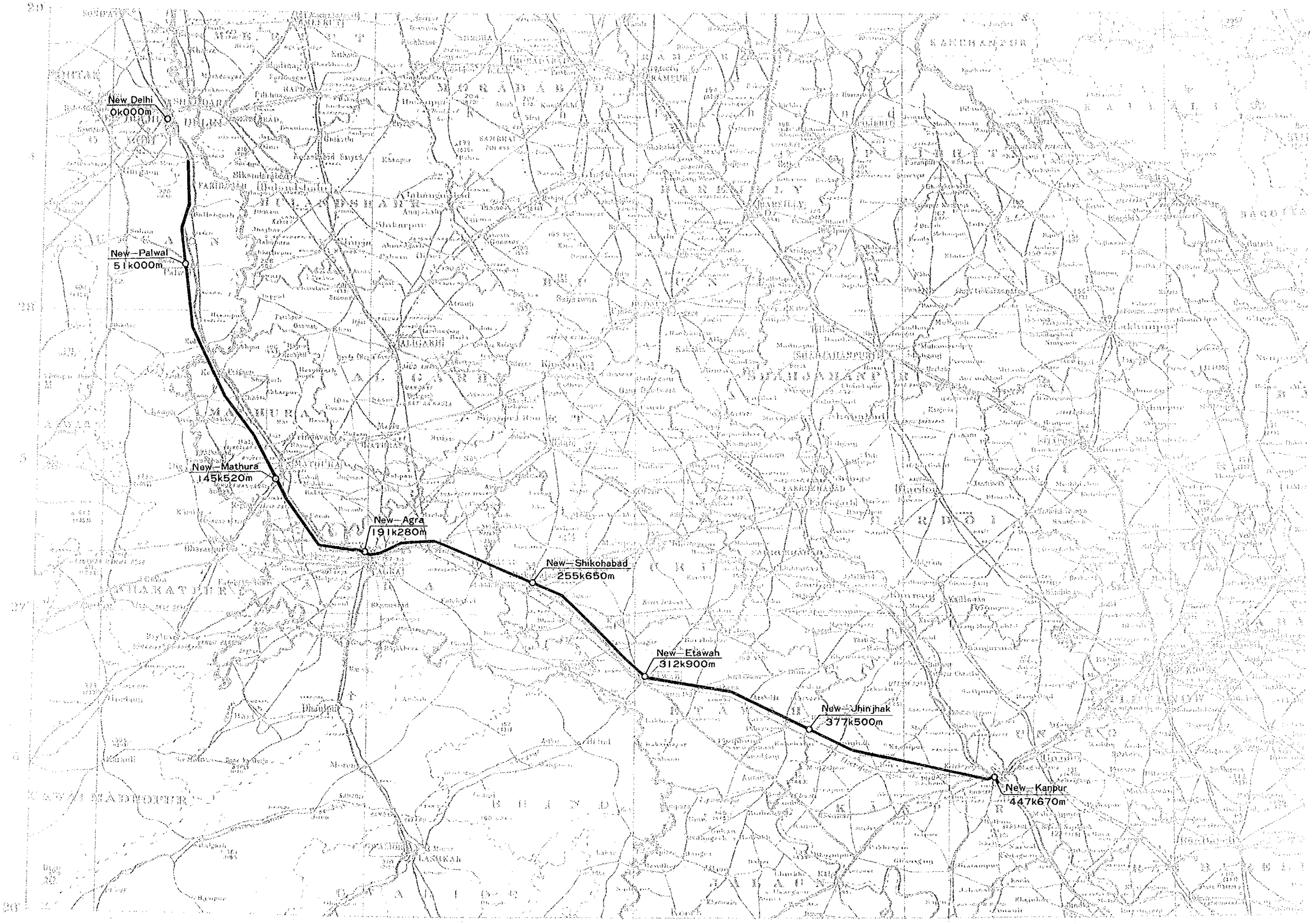
The New Corridor leaves Bilochpura, runs to the north of the Raja-ki-mandi Station, and joins the conventional Raja-ki-mandi - Agra City Line. From this point to the Agra City Station, the conventional line is upgraded and jointly used. The New Corridor passes the southern side of the Belanganj Good Station, crosses over the urban area on elevated track, and reaches the Yamuna River. The Yamuna River Bridge will be about 500 m long with 60 degrees of skew. The New Corridor goes up to the north along the

National Highway No. 2, crosses over the Calcutta Line, makes a large curve to the north of Tundla, passes through Shikohabad, and reaches Etawah. In Shikohabad, the New Corridor is away from the Calcutta Line by 3 km and from the urban area by 1 km. Near this point, the intermediate station is located. And in Etawah, the new station is constructed at 1.5 km north of the conventional station. From here, the New Corridor proceeds to the west along the Calcutta Line about 1 km to the north, passes through the intermediate station located near Jhinjhak, and reaches Panki. In front of the Panki Station, the New Corridor crosses over the Calcutta Line, again crosses over the Jhansi Line near Vivekanandnagar 6 km ahead of Kanpur, proceeds over elevated track along the Jhansi Line, and reaches Govindpuri where the New Kanpur Terminal is located. The extension between New Agra and New Kanpur is 257 km.

The total length of the New Corridor amounts to 448 km.

Fig. 5.2.2-1 shows the New Corridor route map.

Comparison of routes are shown in the Appendix 4-11.


New Delhi
0k000m
New-Palwal
51k000m
New-Mathura
145k520m
New-Agra
191k280m
New-Shikohabad
255k650m
New-Etawah
312k900m
New-Jhinjhak
377k500m
New-Kanpur
447k670m