社会開発協力部報告書

No. 7

REPORT

FOR

THE FEASIBILITY STUDY

ON

RAILWAY IMPROVEMENT PLAN OF TRANSPORT CAPACITY AND TRAIN SPEED ON THE DELHI-KANPUR SECTION

IN

INDIA

SUMMARY

DECEMBER 1987

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

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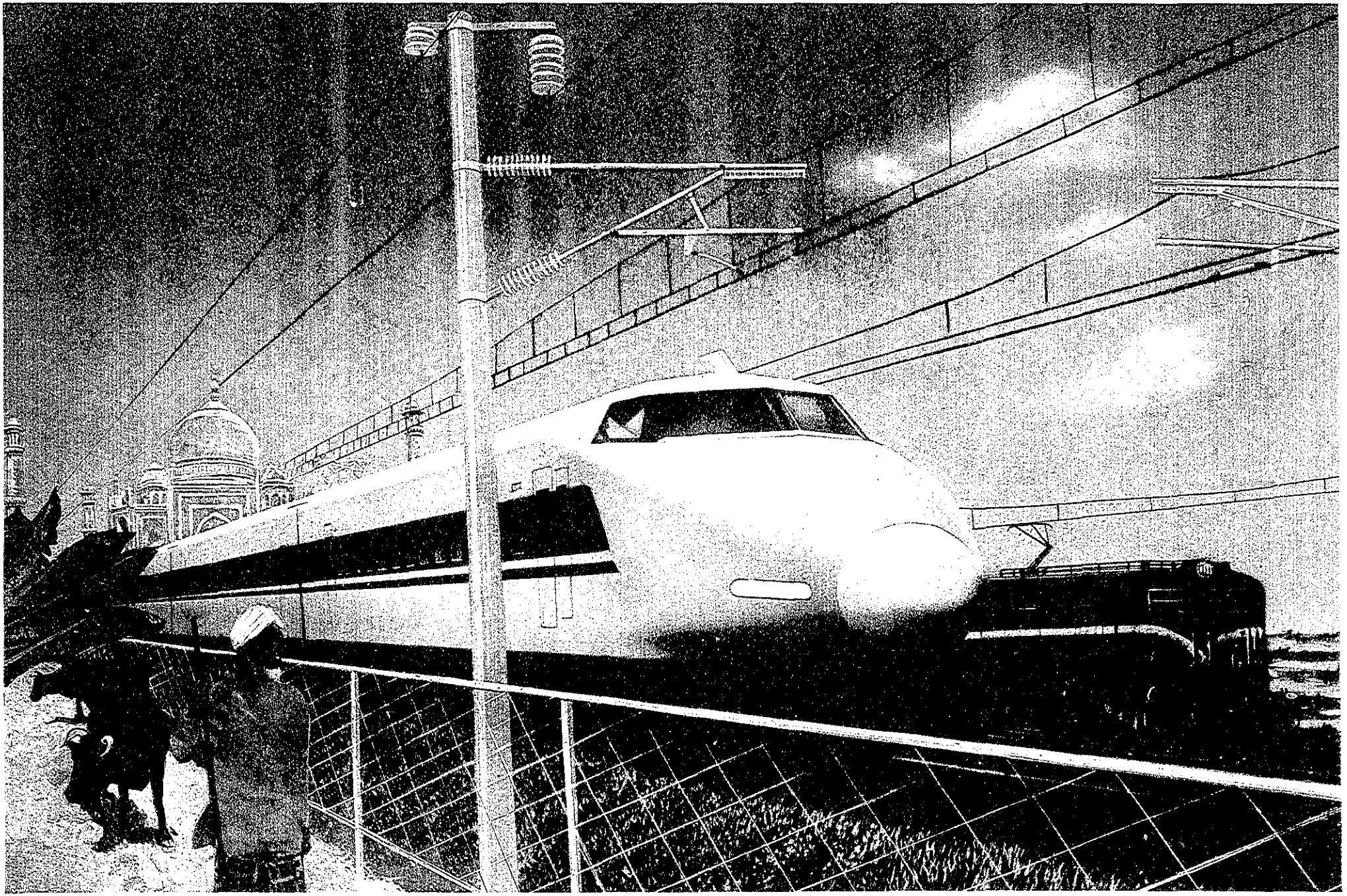

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Exchange Rate

1 Rs = ¥11.35

1 US$ = Rs12.97

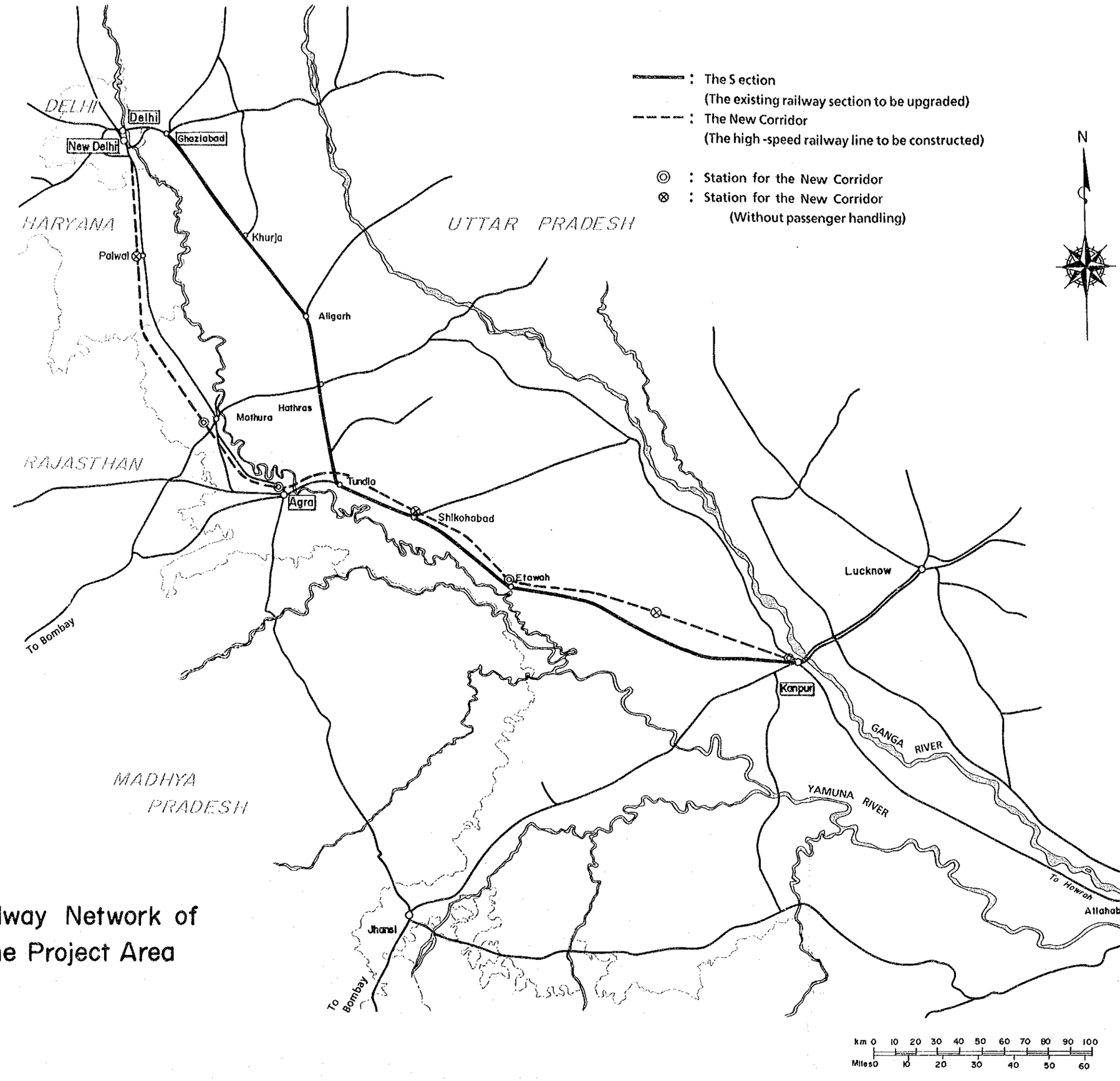
Abbreviation

A/C	Air Conditioned coach
A.F.	Audio Frequency
AT	Autotransformer
ATC	Automatic Train Control
AWS	Auxiliary Warning System
Bo-Bo	Rolling stock composed of two bogies equipped with two motors
Bo-Bo-Bo	Rolling stock composed of three bogies equipped with two motors
CB	Circuit Breaker
CC	Control Center
CIF	Cost Insurance and Freight
CSC	Centralized Substation Control
CTC	Centralized Traffic Control
Delhi U.T.	Delhi Union Territory
DN	Down line
EIRR	Economic Internal Rate of Return
EL	Electric Locomotive
EMU	Electric Multiple Unit
Exp./Mail	Express and Mail passenger train
FIRR	Financial Internal Rate of Return
GDP	Gross Domestic Product
GTO	Gate Turn Off
IR	Indian Railways
JICA	Japan International Cooperation Agency
JR	Japan Railways

L. Exp.	Long Distance Express passenger train
LF	Low Frequency
Local	Local passenger train
OHE	Overhead Equipment
PRC (P.S.C)	Prestressed Concrete
RCC	Remote Control Center
S. Exp.	Super Express train
SP	Sectioning Post
SS	Substation
SSP	Subsectioning Post
TCR	Thyristor Control Reactor
The Section	The existing railway section between Ghaziabad and Kanpur.
The New Corridor	New high-speed railway corridor to be constructed between New Delhi and Kanpur via Agra
TTM	Tie Tamping Machine
UP	Up line
U.P.	State of Uttar Pradesh
V.V.V.F	Variable Voltage Variable Frequency
6M10T	Six motored-car and ten trolley-car train formation

Station Code List

Code	Station	Code	Station	Code	Station
DLI	Delhi	HNG	Hirangaon		(NDLS - AGC)
NDLS	New Delhi	FZD	Firozabad	NZM	Hazrat Nizamuddin
DLSB	Delhi Sadar Bazar	MNR	Makkhanpur	AGC	Agra Cant
VVB	Viveka Vihar Halt	SKB	Shikohabad	AGA	Agra City
TKJ	Tilak Bridge	KAA	Kaurara	MTJ	Mathura
ANVR	Anand Vihar	BDN	Bhadan	TKD	Tuglakabad
SBBB	Sahibabad	BBL	Balrai	PWL	Palwal
GZB	Ghaziabad	JGR	Jaswant Nagar		
C. Buzurg	Chipayana Buzurg	SB	Sarai Bhupat	HWH	Howrah
MIU	Maripat	ETW	Etawah	SDAH	Sealdah
DER	Dadri	EKL	Ekdil	BCT	Bombay Central
AJR	Ajaibpur	BNT	Bharthana	MAS	Madras Central
DKDE	Dankaur	SHW	Samhon	SDAH	Sealdah
WAIR	Wair	ULD	Achalda	HWH	Howrah
CHL	Chola	PTX	Pata	CABP	Calcutta (Amrit
SKQ	Sikandarpur	PHD	Phaphund		Bazar Patrika)
KRJ	Khurja	KNS	Kanchausi	ALD	Allahabado JN
DAR	Danwar	JJK	Jhinjhak	LKO	Lucknow
SOM	Somna	AAP	Ambiapur		
KLA	Kalwa	RRH	Rura	FTH	Fatuhi
MWUE	Mahrawal	RMW	Roshan Mau Halt	HRF	Harhras Qilah
ALJN	Aligarh	MTO	Maitha	ROK	Rohtak
DAQ	Daud Khan	BPU	Bhaupur	KTT	Kota
MXK	Mandrak	PNK	Panki	JAT	Jammu Tawi
SNS	Sasni	GOY	Govindpuri	ASR	Amritsar
HRS	Hathras	GMC	Juhi M. Yard	KLK	Kalka
PORA	Pora	CNB	Kanpur Central	FKD	Farrukhabad
JLS			Jalesar Road		Unchahar JN UCR
CMR	Chamorola			BSB	Varanasi JN
BRN	Barhan			JNM	Jaynagar Majlipur
MTI	Mitawali			KIUL	Kiul JN
TDL	Tundla			GHY	Gauhati
				SBG	Sahibganj



Railway Network of
the Project Area

SUMMARY

1. Objectives of the Study

As a key step to improve the railway transport on the Delhi-Howrah (Calcutta) trunk line (1450 km), feasibility of the two projects which aim at improving railway transportation on the Delhi-Kanpur section (420 km) is studied as follows:

(1) Feasibility study on the project to upgrade transport capacity and train speed (max. 160 km/h) on the existing Delhi-Kanpur railway section.

(2) Pre-feasibility study on the project to construct a new high-speed railway (hereinafter referred to as "the New Corridor") connecting Delhi and Kanpur via Agra and operating passenger trains at the maximum speed of 200/250 km/h.

Upgrading the ground facilities on the Delhi-Ghaziabad section (20 km) is not included in this Study, for overall traffic demand forecast on this section is not available in this Study, since on this section besides Delhi-Kanpur flow, there exists numerous train traffic flows which are out of the scope of this Study such as Delhi-Ghaziabad, Delhi-Moradabad, Ghaziabad-Tuglakabad and Delhi-Saharanpur flows.

The train operation plans after completion of the above two projects are prepared on the assumption that necessary improvements in track capacity on the Delhi railway networks beyond Ghaziabad and on the Kanpur-Howrah section will be made in line with the implementation of these two projects.

2. Socio-economic Framework

Annual population and GDP growth rates as the base for this Study are assumed as follows:

Table 2-1 Annual Population Growth Rate

Zone \ Year	1986-1990	1991-1995	1996-2000	2001-2015
Inner zone	2.54	2.46	2.14	1.88
Outer zone	1.93	1.75	1.55	1.36
Total	1.96	1.78	1.58	1.39

Inner zone: Area directly related with the Project (Delhi Union territory and a part of the State of Uttar Pradesh)

Outer zone: Other parts of the country

Annual GDP growth rate

1986 - 1999 5%

2000 - 2015 4%

Table 2-2 Future Gross Regional Domestic Product

Item \ Year		1985/86	1990/91	1995/96	2000/2001	2015/16
GRDP (Rs.CRORES)	Delhi Union Territory	1,215	1,551	1,979	2,526	4,550
	Uttar Pradesh	8,385	10,702	13,659	17,433	31,390
GRDP per Capita (Rs.)	Delhi Union Territory	1,625	1,707	1,807	2,001	2,485
	Uttar Pradesh	695	799	921	1,068	1,499

In estimating the socio-economic framework up to 1990, indicators planned in the 7th Five Year Plan are mainly adopted. For estimation beyond 1990, data from such materials as the Delhi Union Territory's Master Plan, Registrar General's population estimation are used.

The map below shows the Inner zone set up for this Study.

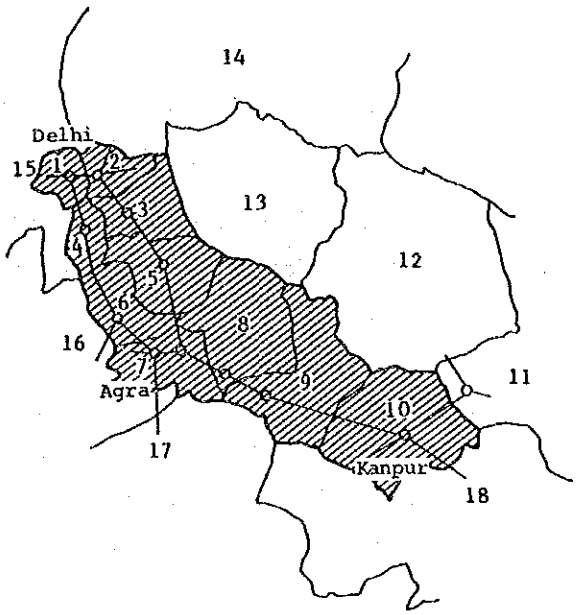


Fig. 2-1 Inner Zone of the Project

3. Establishing the Guidelines for the Study

As a preliminary step of the Study, the guidelines for the Study are established by selecting the optimum implementation strategies of the two projects among nine alternatives - in terms of railway section/route, train speed and fare structure - by estimating the generalized cost difference between 'With' and 'Without' the project cases.

As a study result, the general guideline is set up as follows:

(1) The Ghaziabad - Kanpur Section (hereinafter referred to as "the Section") will be upgraded in 1991 in terms of transport capacity and train speed (max. 160 km/h).

(2) The New Corridor connecting Delhi and Kanpur via Agra will be constructed around 2000. The maximum train speed of the Super Exp. train will be 250 km/h and its fare will be higher than that of the existing 2nd class Mail/Exp. train to some extent.

Alternatives are set up based on the following staged-improvement strategy which is considered most pragmatic from the techno-economical viewpoint; i.e., to change the transport capacity of the Section, which has been fully occupied, in coordination with the related improvements scheduled in the 7th Five Year Plan, and afterwards to construct a New High-Speed Corridor line to cope with the traffic demand increase envisaged from a longer viewpoint.

a) Case I (Alternative I)

The Section is upgraded both in terms of transport capacity and travelling time. The maximum train speed will be improved up to 160 km/h.

b) Case II (Alternative II-1, II-2, II-3, II-4)

In addition to upgrading the Section; the New Corridor is constructed from Delhi up to Agra.

(Existing link between Agra and Tundla is upgraded)

In Case II, four alternative plans are set up, taking into account the combined conditions of the maximum train speed (200 km/h or 250 km/h) and passenger fare level of the New Corridor (higher fare level by 25% or 50% than that of 2nd Class Exp./Mail train of the conventional line).

c) Case III (Alternative III-1, III-2, III-3, III-4)

In addition to upgrading the Section, the entire length of the New Corridor connecting Delhi and Kanpur via Agra is constructed.

In Case III, four alternative plans are set up for the same conditions mentioned in Case II.

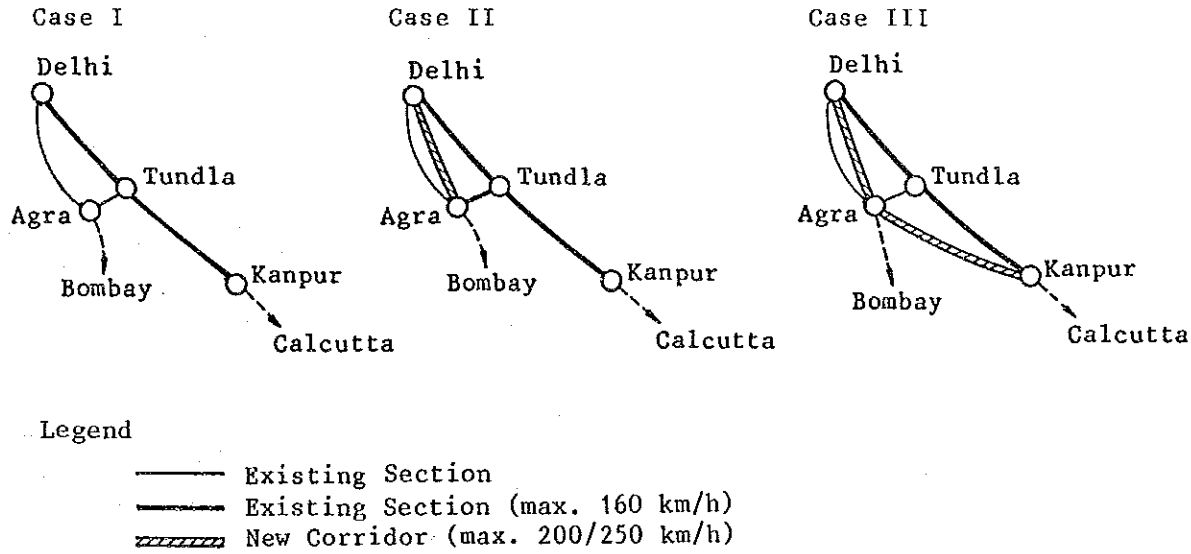


Fig. 3-1 Alternative Plans

Difference of the Generalized Cost ΔE is given by the following formula.

$$\Delta E = W\Delta T + \Delta C$$

where: W : Passenger time value

ΔT: Passenger time saving due to implementing the alternative plan

ΔC: Cost saving (capital cost and operating cost) due to implementing the alternative plan

Table 3-1 shows the time saving benefit, cost saving benefit and ΔE in percentage figures, with ΔE of alternative I as 100.

Table 3-1 Comparison of the Generalized Cost Difference (ΔE)

Year / Benefit / Alternative Plan		1990			1995			2000			2015		
		Time saving	Cost saving	Total ΔE	Time saving	Cost saving	Total ΔE	Time saving	Cost saving	Total ΔE	Time saving	Cost saving	Total ΔE
I	Upgrading the Section	8	92	[100]	9	91	100	10	90	100	14	86	100
II-1	New Corridor DLI-AG 200 km/h, 25% up	12	64	76	13	79	92	14	84	98	20	80	100
II-2	New Corridor DLI-AG 200 km/h, 50% up	11	66	77	12	81	93	14	85	99	19	81	100
II-3	New Corridor DLI-AG 250 km/h, 25% up	13	61	74	15	78	93	16	83	99	22	80	102
II-4	New Corridor DLI-AG 250 km/h, 50% up	11	63	74	13	79	92	14	84	98	20	80	100
III-1	New Corridor DLI-CNB 200 km/h, 25% up	38	37	75	26	68	94	26	78	104	59	80	139
III-2	New Corridor DLI-CNB 200 km/h, 50% up	20	38	58	20	70	90	21	78	99	44	78	122
III-3	New Corridor DLI-CNB 250 km/h, 25% up	41	32	73	34	71	[105]	35	79	[114]	69	78	[147]
III-4	New Corridor DLI-CNB 250 km/h, 50% up	26	34	60	24	67	91	25	78	103	55	77	132

Note: Total ΔE of Case I for each sample year is set at 100.
"25% up" and "50% up" mean that fare level of the Super. Exp. train of the New Corridor is set at higher level than that of 2nd class Exp./Mail train of the Section by 25% and 50% respectively.
Figures in quadrangles show the largest ΔE value in each year.

4. Planned Railway Traffic Volume

Increase in railway traffic volume by implementing the two projects is estimated taking into account traffic demand forecast and improved traffic capacity as follows:

(1) Upgrading the Section (Ghaziabad-Kanpur) in 1991

As a result of upgrading the railway assets of the Section, passenger and freight traffic are almost doubled during the period between 1991 and 2000, i.e., railway traffic of 8.0 billion passenger-km/year and 13.7 billion ton-km/year in 1990 will grow to 15.6 billion passenger-km/year and 25.5 billion ton-km/year in 2000, respectively.

After 2000, however, traffic will not increase due to saturation of track capacity.

Traffic growth planned by upgrading the Section is shown below.

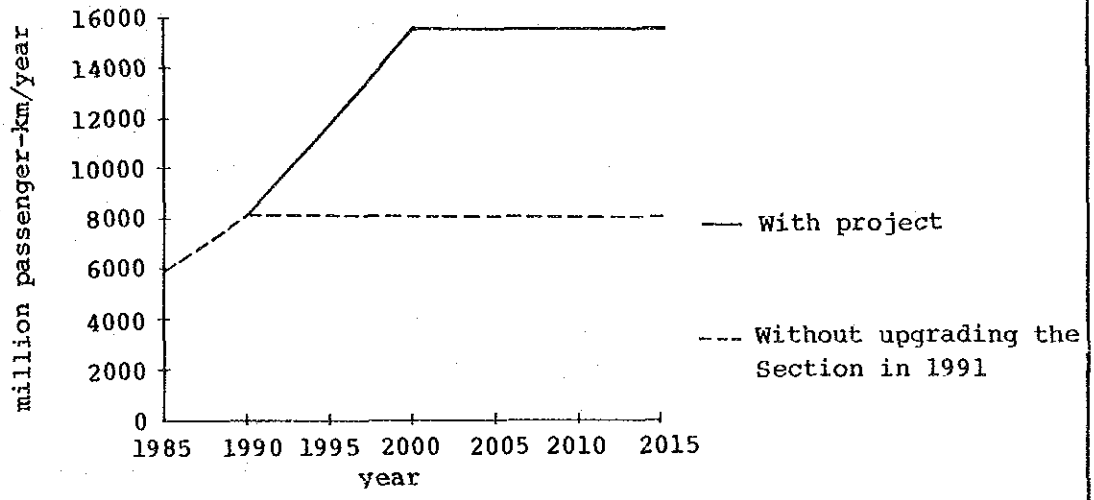


Fig. 4-1 Planned Passenger Traffic after Upgrading the Section in 1991 (Existing Ghaziabad-Kanpur Section)

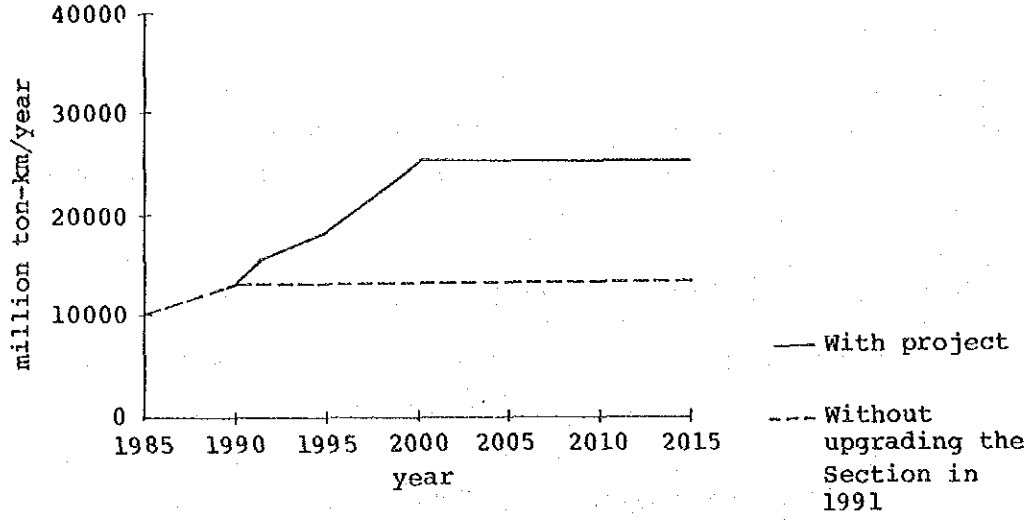


Fig. 4-2 Planned Freight Traffic after Upgrading the Section in 1991 (Existing Ghaziabad-Kanpur Section)

(2) Constructing a New High Speed Corridor (Delhi-Agra-Kanpur) in 2000, in addition to upgrading the Section in 1991

After construction of the New Corridor, due to sharp reduction in travelling time, passengers will divert from bus, air and conventional railway to the New Corridor, along with induced traffic, although the degree of diversion to the New Corridor will be greatly affected by its fare level: the cheaper the fare, the greater the passenger volume.

Railway traffic of the Section and the New Corridor are forecasted for five cases of passenger fare level of the Super Exp. train (i.e., higher fare levels by 0, 25, 50, 75 and 100 percent than that of 2nd class Exp./Mail train of the Section). In case of fare level of 25 percent, total railway passenger traffic of the two railway lines will increase from 15.6 to 30.8 billion passenger-km/year in 2000 and reach to 48.3 billion passenger-km/year in 2010. On the other hand, by diverting passenger traffic from the Section to the New Corridor, freight traffic on the Section will increase from 25.5 billion ton-km/year in 2000 to 37.8 billion ton-km/year in 2010.

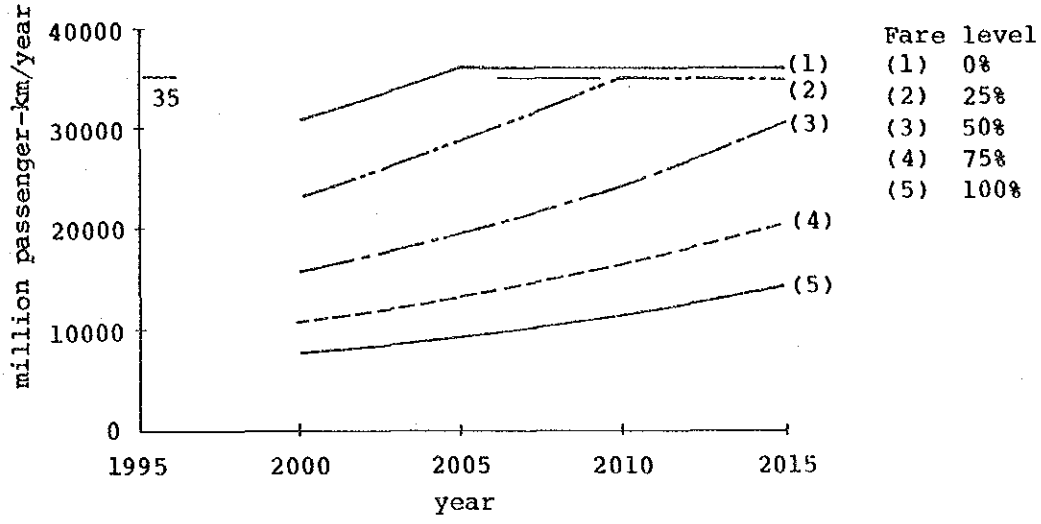


Fig. 4-3 Planned Passenger Traffic after Constructing the New Corridor in 2000 (New Corridor between Delhi and Kanpur)

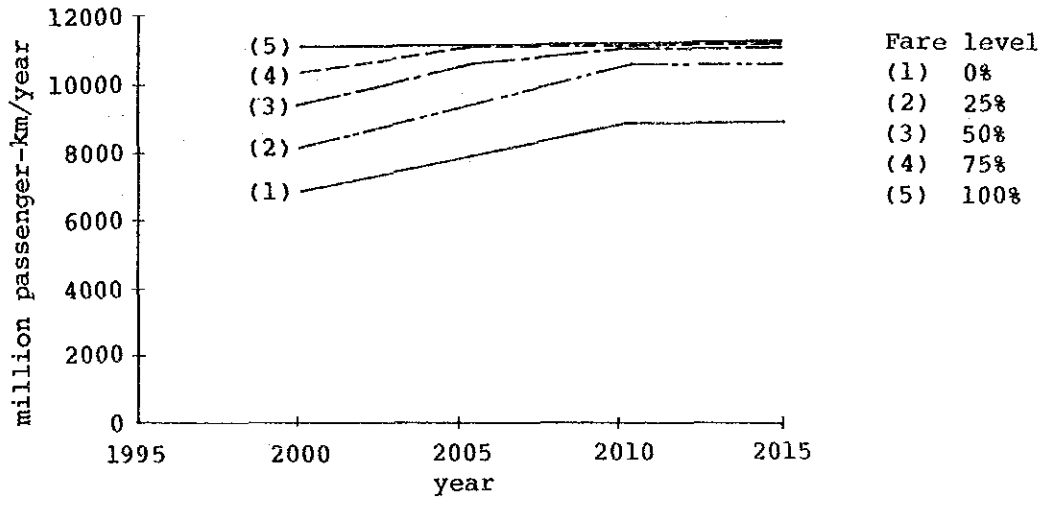


Fig. 4-4 Planned Passenger Traffic after Constructing the New Corridor in 2000 (Existing Ghaziabad-Kanpur Section)

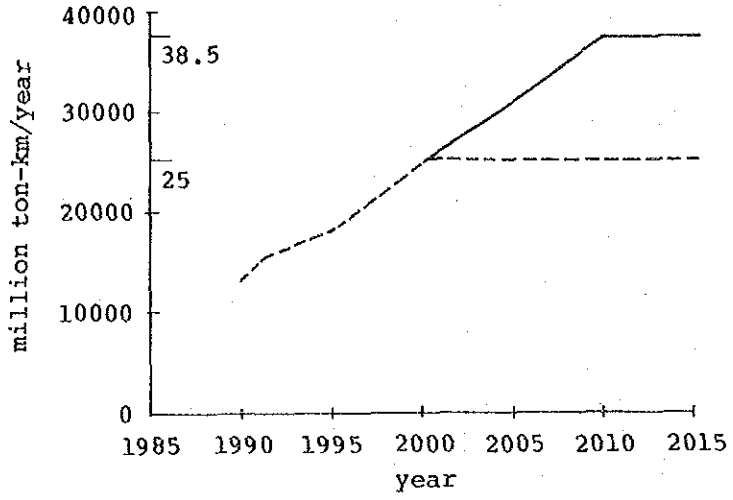


Fig. 4-5 Planned Freight Traffic after Constructing the New Corridor in 2000 (Existing Ghaziabad-Kanpur Section)

_____ With constructing the New Corridor in 2000

------ With upgrading the Section in 1991

The diverted traffic from bus, truck and airplane to railway, and induced railway traffic due to improved railway service are estimated as shown below.

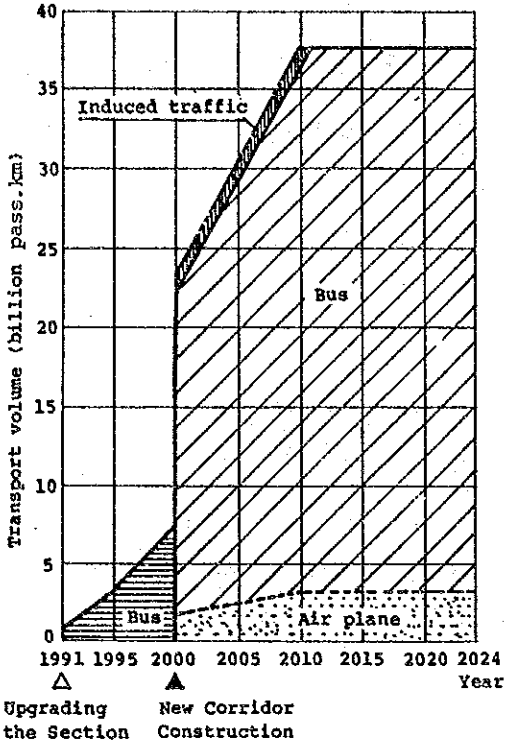


Fig. 4-6 Diverted and Induced Railway Traffic (Fare level of 25%)

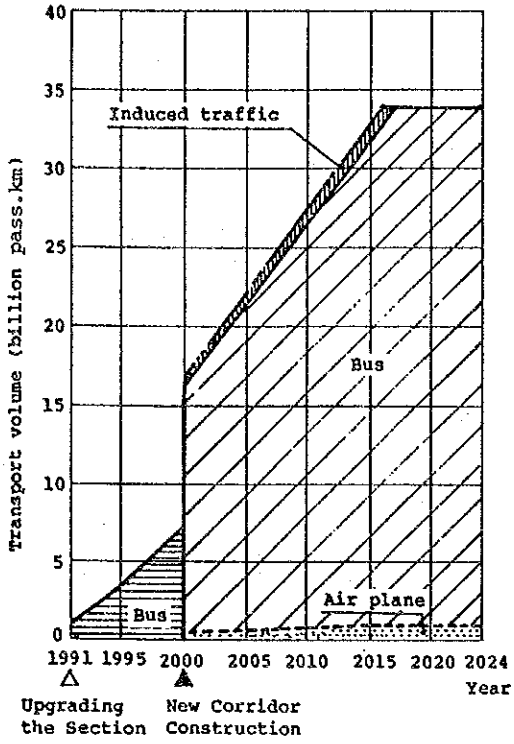


Fig. 4-7 Diverted and Induced Railway Traffic (Fare level of 50%)

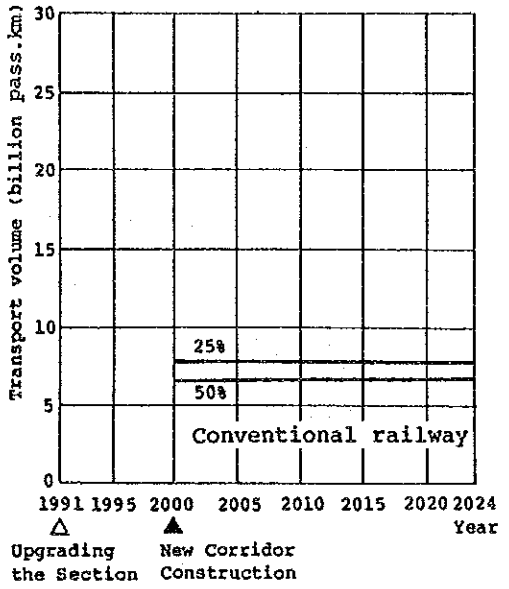


Fig. 4-8 Diverted Traffic from Conventional Railway to the New Corridor (Fare level of 25, 50%)

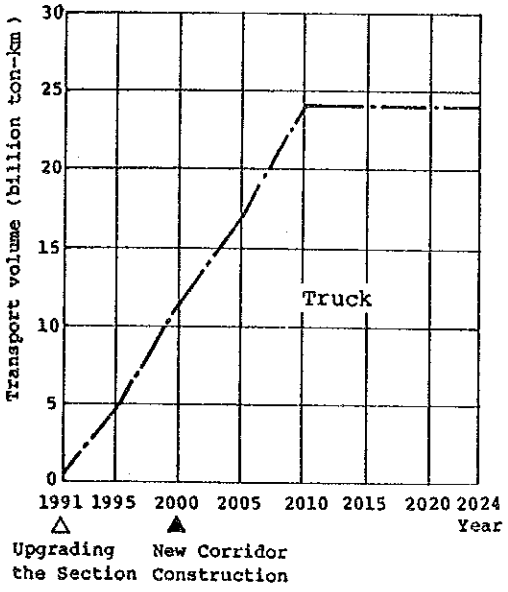
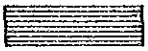
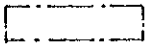
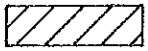


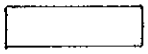
Fig. 4-9 Diverted Freight Traffic

 : Diverted passenger traffic from bus to the Section

 : Diverted freight traffic from truck to the Section

 : Diverted passenger traffic from bus to the New Corridor and the Section

 : Diverted passenger traffic from airplane to the New Corridor

 : Diverted passenger traffic from the conventional railway (including the Section) to the New Corridor.

 : Induced Traffic to the New Corridor.

Traffic demand is forecasted by the four step method for railway, road and air traffics based on the following premises.

a. Railway

Passenger

(a) The Section

. Commercial (max.) speed (km/h)

L. Exp. : 102 (160)
Exp./Mail : 70 (130)

. Passenger fare level (Rs/pass.km)

L. Exp. : 0.36 (Equivalent level to that of Rajdhani Exp. train)

Exp./Mail: 0.11

(b) The New Corridor

i) Super Exp. train

. Commercial (max.) speed: 170 km/h (250 km/h)

. Passenger fare level (Rs/pass.km)

A higher fare level by 0.11 (0%), 0.14 (25%), 0.17 (50%), 0.19 (75%) or 0.22 (100%) than that of 2nd class Exp./Mail train.

ii) L.Exp. train

. Commercial (max.) speed: 120 km/h (160 km/h)

. Passenger fare level : 0.36 Rs/pass.km

Freight

Present commercial speed and freight traffic structure, are assumed to remain unchanged in the future.

b. Road and Air

Present travelling time and relative fare/tariff structure of the long-distance bus/truck and airplane are assumed to remain unchanged in the future.
(Air: 1.00 Rs/pass.km, Bus: 0.09 Rs/pass.km)

c. Time Value

The time value is assumed to grow with the growth of GDP per capita of the Inner zone (i.e., Delhi area and a part of the State of U.P. related to this Project) keeping the present distribution pattern.

5. Upgrading the Existing Section

(1) Transport plan

By upgrading the rolling stock and ground facilities of the Ghaziabad-Kanpur section, the train traffic between Delhi and Kanpur is improved both in traffic volume and travelling time.

a. Basic conditions of transport plan

Existing Raj. Exp. trains are replaced with Long-distance Exp. (L. Exp.) trains which run at the max. speed of 160 km/h. Max. train speeds of Exp./Mail, Local passenger and Fast freight trains are also improved as follows:

Table 5-1 Basic Conditions of Transport Plan (The Section)

Train type		Ratio of train number (%)	Max. speed (km/h)		Average passenger carrying/freight hauling capacity		Average number of coaches/wagons per train	
			Present	Upgraded	Present	Upgraded	Present	Upgraded
Passenger	L. Exp. (Raj. Exp.)	3	(120)	160	(880)	(1,090)	(18)	18
	Exp./Mail	41	105	130	1,050	1,150	18	19.5
	Local	6	90	105	761	1,200	10.6	18
Freight	Fast	21	75	90	4,500 (tons)	4,500 (tons)	56	56
	Ordinary	29	75	75	2,250 (tons)	2,250 (tons)	28	28

b. Track capacity and number of trains

The present track capacity (101 trains per day) which is now fully occupied will be improved by 10 percent by 1990 through implementing related upgrading plans of the 7th Five Year Plan. By completing the Upgrading Project in 1991, track capacity of the Section will be almost doubled (206 trains per day); nevertheless, this capacity will be fully occupied by 2000.

Presumed track capacity and train number up to 2000 are shown below.

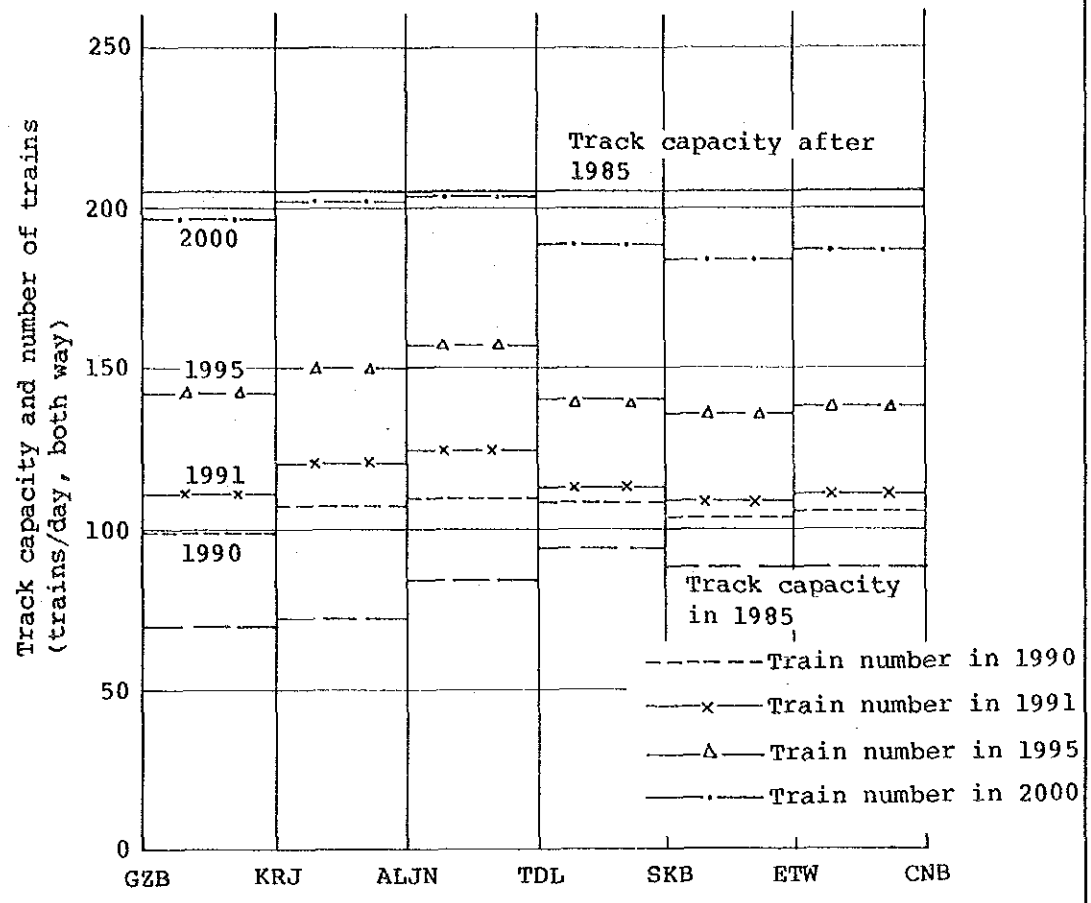


Fig. 5-1 Yearly Number of Trains and Track Capacity of the Section

c. Travelling time

Travelling time of Exp. trains are considerably shortened as shown below:

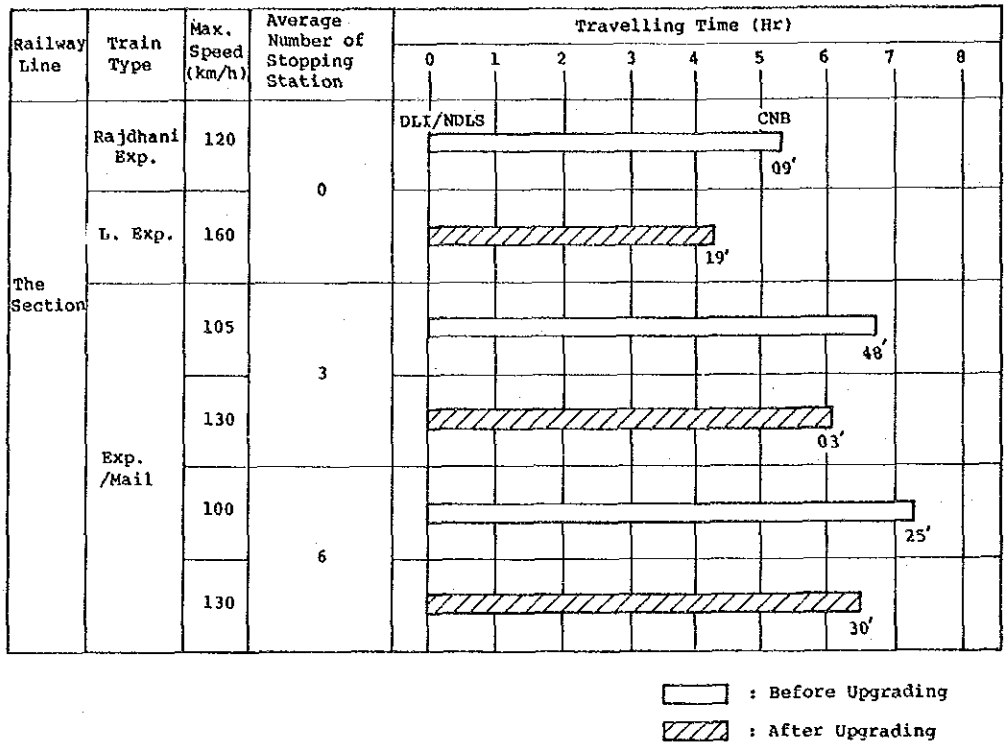


Fig. 5-2 Travelling Time (Delhi - Kanpur)

In preparing the operation plan, present stopping/margin time and load factor are adopted, and maintenance block of 2 hours to be provided separately for UP and Down lines is secured in the daytime zone.

The track capacity in 1990 is estimated in view of related upgrading plans of the Section which are included in the 7th Five Year Plan.

(2) Rolling stock

Max. train speed and carrying capacity of each type of train are improved, by upgrading Electric Locomotive (EL), coach, wagon as well as their braking system as shown below:

Table 5-2 Rolling Stock Improvement Plan (The Section)

[ ] : Upgraded points
↓ : To be replaced in future

Train		Max. speed (km/h)	Hauling tonnage (t)	No. of coaches/ wagons	E.L.	Coaches & wagons	Brake (max. brake distance: 2 km)
PASSEN-GER	L. Express	160	700	18	Thyristor phase/ 3-phase control hauled with two ELs	High speed coach	Air (Electro-magnetic control)
	Ex./Mail	100,105 ↓ 130	1,000	18 ⟆ 21	WAM4 ↓ WAP1	Coaches used for Rajdhani Exp.	Vacuum ↓ Air
	Local	75 ↓ 105	1,000	18	WAM1 ↓ WAM4 ↓ WAP1	Coaches currently used for Local ↓ Ex./Mail	Vacuum ↓ Air
FREIGHT	Fast	75 ↓ 90	4,500	56	WAG5 ↓ WAG6	BOXN & BCN	Air
	Ordinary	72 ↓ 75	2,250 (3,300)	28 (40)	WAG4 ↓ (WAG5)	BOX & BCX ↓ BOXN & BCN	Vacuum ↓ Air

a. L. Exp. train

To attain high acceleration, L. Exp. Train is hauled by two electric locomotives (ELs).

As for EL type, common use of 4500 KW Bo-Bo-Bo type EL (WAG6) with fast freight train by changing gear ratio is recommended. In the near future, however, introduction of 3,500 KW Bo-Bo type EL using 3-phase asynchronous motor will become feasible.

b. Exp./Mail train

EL and coach currently used for the Rajdhani Exp. train is adopted with some train-formation modification to improve train speed and carrying capacity.

c. Fast Freight train

WAG6 type EL and high-speed wagon equipped with air brake are used to attain higher carrying capacity and speed.

d. Local Passenger train and Ordinary Freight train

Brake system is upgraded from vacuum to air brake type taking the opportunity of replacing aged rolling stock.

(3) Track and structure

In order to enable high-speed train operation at 160 km/h and track capacity increase as well as to eliminate existing permanent speed restrictions, following upgradings are implemented on the premise that the track renewal work (i.e., 52 kg continuous welded rail, PRC 1,540/km sleeper, 30 cm-thick-ballast, etc.) and provision of loop lines to loopless way-stations will be completed not later than 1990.

a. To improve the cant of 70 curves and transition curve of 34 curves to meet the maximum train speed of 160 km/h.

b. To upgrade 333 turnouts on main tracks to eliminate speed restriction for run-through trains at 160 km/h and to alleviate branch-off speed restriction from 10/15 km/h to 40 km/h.

c. To provide new run-through loops separated from platforms at Aligarh and Etawah Stations and security fences on the 37 platforms to ensure the security of passengers.

d. To improve train handling capacity of the Kanpur station by adding a platform and two loops.

e. To improve 187 turnouts and track layout of the Ghaziabad, Tundla, and Juhi yard to eliminate/alleviate speed restrictions.

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

g. To install security fences along the entire railway tracks to secure safety of high-speed train operation as well as of pedestrians/cattle.

The aforementioned improvements will allow 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 considerably improve the existing track capacity.

a. Turnouts on the run-through tracks are upgraded to 1 in 12 (60 kg) improved type turnout (i.e., elastic type switch, gas pressure welded crossing, H-type guard, etc.)

b. The new track structure has sufficient bearing power to allow train operation at 160 km/h with axle load of 19.5/20.5 tons.

c. To cope with the increase in the passing tonnage and train speed, further upgrading of track structure to 60 kg/m rail, 1,660 PRC sleepers/km and ballast thickness of 30 cm is recommended.

d. In 2000, passing tonnage and average train speed will reach levels 2.34 and 1.19 times larger than those in 1985, and even with implementation of such track reinforcement, wear of track will grow by 80%, thus necessitating introduction of more mechanized and efficient track maintenance system.

(4) Signalling and telecommunications

To improve track capacity, automatic block system is introduced. To Cope with increased train speed and traffic capacity, safety of train operation is secured by solid state/relay interlocking device, automatic level crossing protection device, and auxiliary train warning system (AWS), and traffic control function is upgraded by CTC, as shown below:

Table 5-3 Signalling and Telecommunication Improvement Plan

Device/Equipment	Present	Upgrading
Block device	Double line lock & block	Automatic block
Signal indication	G-Y-R (Home & starter signal) G-YY-Y (Distant signal) G-R (Advanced starter signal)	G-YY-Y-R (Inter-station area) G-YY-(Y+ 40)-(YU+ 40)-R (Home signal with branch-off speed restriction)
Train detection	DC single rail track circuit	AF non-insulated track circuit
Interlocking device	Relay type = 12 stations 21 block huts Mechanical type: 38 stations	Solid-state type = 38 stations Relay-type: 12 stations
Level crossing Protection device	Hand-operated gate/barrier : 166 (manned) (51 are interlocked with gate signal)	Automatic barrier control: 166 (manned) Fixed barrier-closing time control = 2 min. (All barriers are interlocked with gate (= block) signal)
Train protection device	None	AWS with speed check function (Transponder and speed pattern type)
Traffic control system	Control telephone	CTC Traffic/passenger information device

a. In view of the braking distance of 2 km and the high track capacity required, the minimum block length is determined as 1 km.

b. G-YY-Y-R aspect conforms to that currently used in the Delhi-Ghaziabad section.

c. By introduction of the fixed barrier-closing-time control method, road-traffic suspension can be maintained below the current level even in 2,000 when train density will double the present level with widened difference in train speed. Barrier operation is automated, although gate men are posted for emergency operation.

d. AWS is provided for L. Exp. trains, in the initial stage, and subsequently for other trains. To minimize unnecessary speed restriction caused by delayed gate signal clearance, i.e., delayed barrier lowering, additional transponders are installed at approaches to the level crossings.

e. CTC will control way-stations, and measures to maintain consistency with the train traffic control system of Delhi area is taken.

f. It is assumed that the almost fully occupied 120 CH microwave link will be upgraded by 1990 in separate project.

(5) Electrification

To cope with sharp increase in load current and train speed increase, improvements are made with a premise that additional 6 sub-stations (12.5 MVA, 2 banks) will be installed by separate project not later than 1990 as shown below.

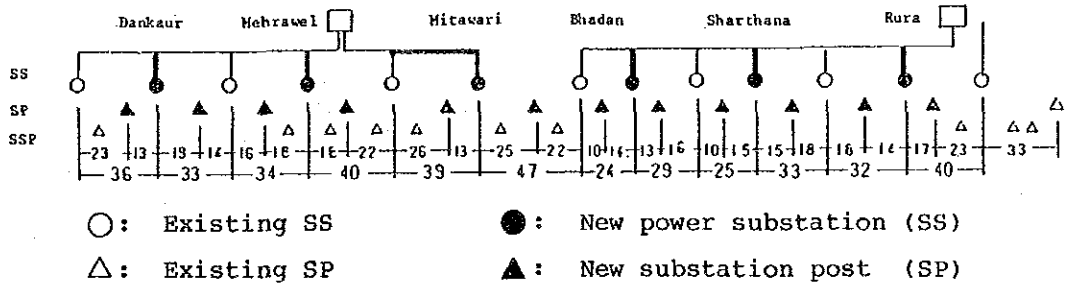


Fig. 5-3 New Power Supply System

a. To alleviate railway traffic hindrance caused by frequent tripping of circuit breaker, various measures to avoid the causes of trippings and to minimize the power stopping time are introduced.

b. To meet high speed train operation at 160 km/h, necessary modifications are made to the overhead equipment (OHE).

Table 5-4 Technologies to be Introduced to Achieve Stable Power Supply

Causes of trippings	Countermeasures
1. Birds	- Protective net against birds
2. Flashover of the air-gap on the roof of EL	- Gapless arrester
3. Flashover of the OHE insulator	- Cleaning of insulator, if necessary
4. False working of distance relay	- Distance relay with parallelogram characteristics instead of MHO relay

Measures to minimize power stopping time	Measures
1. Shorten the power stopping time	- Automatic reclosing of CB - Automatic sequential operation of interrupters
2. Shorten the fault detecting time	- Fault locator

Table 5-5 Major modification of Overhead Equipment (OHE)

Equipment	Current	Modified
Tension of catenary and contact wire	1,000 kgf	1,200 kgf
Presag of contact wire	1.4/1000	0.8/1000 - 1.0/1000
Max. gradient of contact wire	3/1000	1/1000
Allowance between bracket register arm and contact wire	150 mm	200 - 250 mm

(6) Investment cost

Table 5-6 Initial Investment

(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 in 1990	1,010.5		1,010.5
Total	2,082.4	299.1	2,381.5

Table 5-7 Additional Investment

(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

Major premises of the investment cost estimation are as follows:

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

b. Costs of imported equipment and materials are priced in CIF.

c. The foreign exchange rate is Rs1 = ¥11.35.

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

(7) Implementation schedule

Table 5-8 Implementation Schedule (The Section)

(10^6Rs)

Item \ Fiscal year				1987	1988	1989	1990
Schedule	Feasibility study			———			
	Fund raising				———		
	Ground facilities	Designing			———	———	
		Manufacturing				———	———
		Construction	Track/ structure			———	———
			Signalling/ telecommunication				———
			Electrification				———
	Rolling stock	Designing			———	———	
		Manufacturing				———	———
	Running test (160 km/h)						———
Investment	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

6. Construction of a New High-speed Corridor

(1) Basic conditions

a. The New Corridor is planned to enter operation in 2000.

b. The transport plan of the New Corridor is planned based on fare levels that will cause passengers of bus/airplane as well as of the Section to divert to the New Corridor.

c. In planning the rolling stock and ground facilities, new technologies will be employed taking account of social, natural and industrial conditions of India.

d. The Super Express trains of the maximum speed of 250 km/h will shuttle on the New Corridor.

e. The Long distance Express (L. Express) train will run into or out of the New Corridor at Delhi, Agra and Kanpur.

f. 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.

g. The maximum grade will be 5/1000 or less and the minimum curve radius will be 4,000 meters except in the station compounds.

h. Every crossing with conventional railway lines and roads will be of grade separation.

(2) Route and station

a. Station

i) New Delhi terminal station

Two platforms and four loops for the New Corridor trains are constructed in the existing New Delhi station.

ii) New Agra station

New Agra station is constructed at the northern side of the Bilochpura station.

iii) New Kanpur terminal station

New Kanpur station is constructed at the southern side of the Govindpuri station. The terminal will be of elevated station.

iv) Intermediate station

5 intermediate stations, 3 of which are non-passenger handling station, are constructed.

b. Route

i) New Delhi - New Agra (approx. 190 km)

The New Corridor branches off the conventional line at Tuglakabad (located at 19 km south of New Delhi), and comes down along the Bombay line up to the New Agra station.

ii) New Agra - New Kanpur (approx. 260 km)

Crossing the urban area of Agra City on elevated track, the New Corridor reaches the Yamuna River Bridge of about 500 m long. Then, proceeds to the west along the Calcutta line to the elevated New Kanpur station.

(3) Transport plan

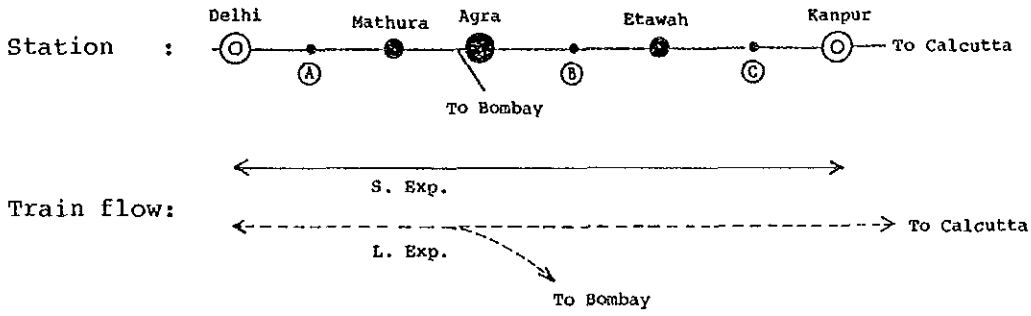
On the New Corridor, Super Exp. trains shuttle between Delhi and Kanpur via Agra with the max. speed of 250 km/h. In addition, L. Exp. trains of the max. speed of 160 km/h is diverted from the existing section.

On the existing section, due to diversion of considerable number of long and medium distance passengers to the New Corridor, the number of passenger trains will decline. And by allocating thus created room of track capacity, freight traffic demand can be met until 2010 at the earliest.

a. Basic conditions of transport plan

Table 6-1 Basic Condition of Transport Plan (The New Corridor)

Train	Train number ratio		Maximum speed (km/h)	No. of coaches	Carrying capacity (Pass./ train)	Stopping station		
	DLI-AGC	AGC-CNB				For passenger handling		For train overtaking
L. Exp.	2	1	160	18	1,090	Delhi Agra Kanpur		Mathura Etawah Ⓐ Ⓑ Ⓒ
S. Exp.	18	15	250	16	1,560	ⓐ	Delhi Agra Kanpur	-
						ⓑ	Delhi Mathura Agra Etawah Kanpur	



b. Number of trains

Track capacity of the New Corridor is around 150 trains per day for both way, and a larger number of trains are operated on the Delhi - Agra section than on the Agra - Kanpur section.

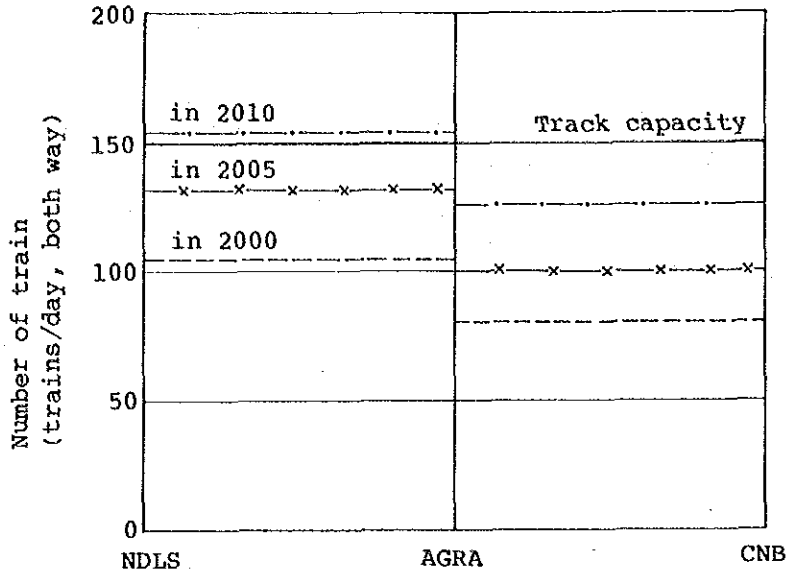


Fig. 6-1 Trend of Train Number Increase (The New Corridor)
(For fare level of 25%)

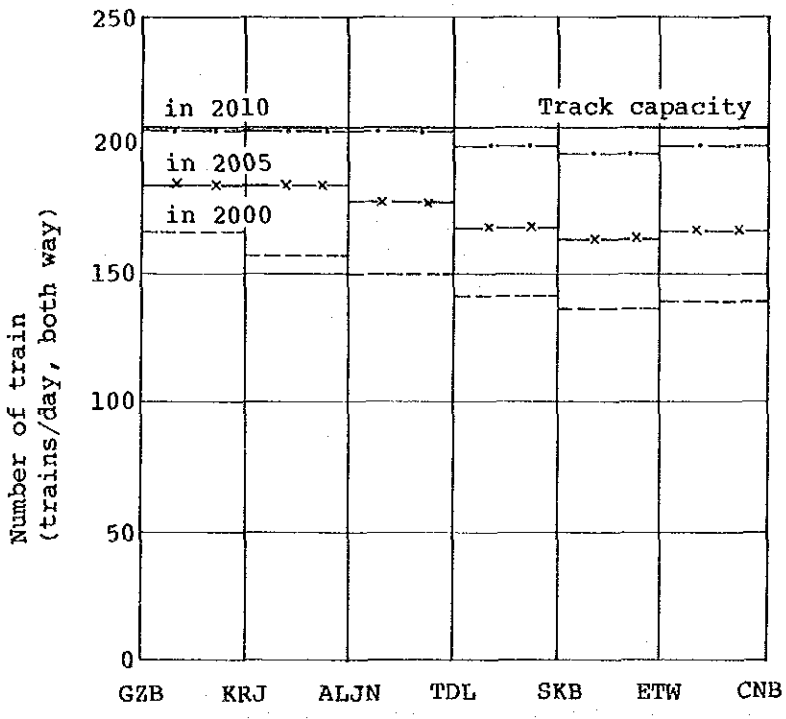


Fig. 6-2 Trend of Train Number Increase (The Section)
(For fare level of 25%)

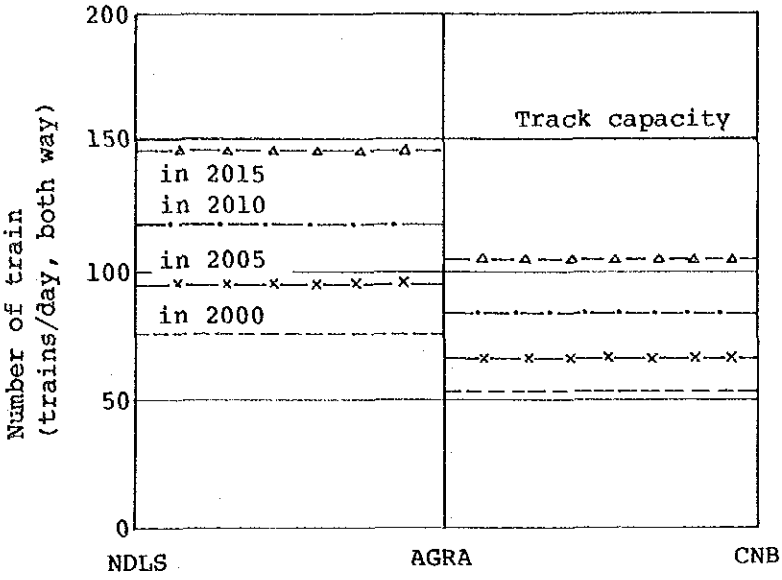


Fig. 6-3 Trend of Train Number Increase (The New Corridor)
(For fare level of 50%)

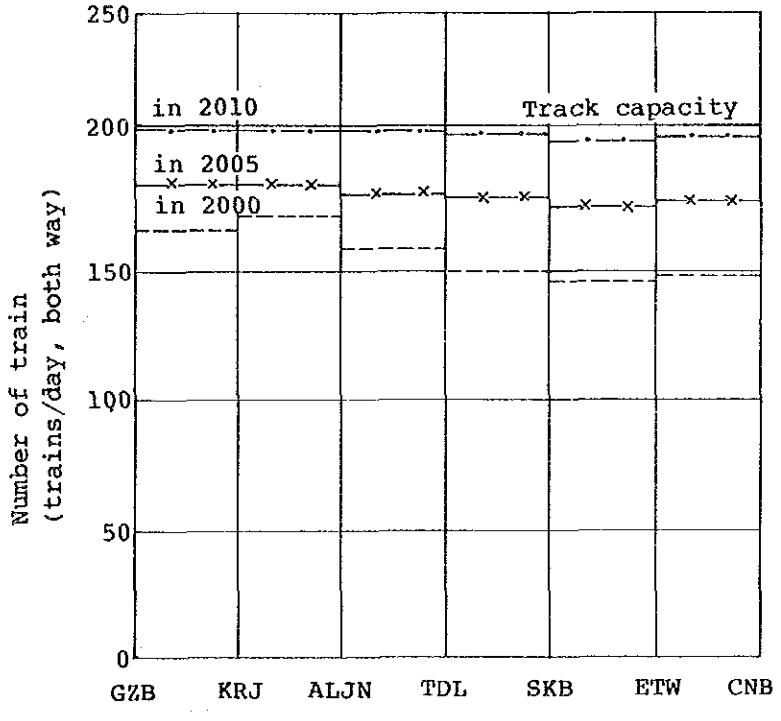


Fig. 6-4 Trend of Train Number Increase (The Section)
(For fare level of 50%)

c. Travelling time

Travelling times between Delhi and Kanpur, and Delhi and Agra by Super Exp. train are almost halved, i.e. 2 hr 35 min. and 1 Hr 5 min. respectively, compared with those by Rajdhani and Taj Exp. trains.

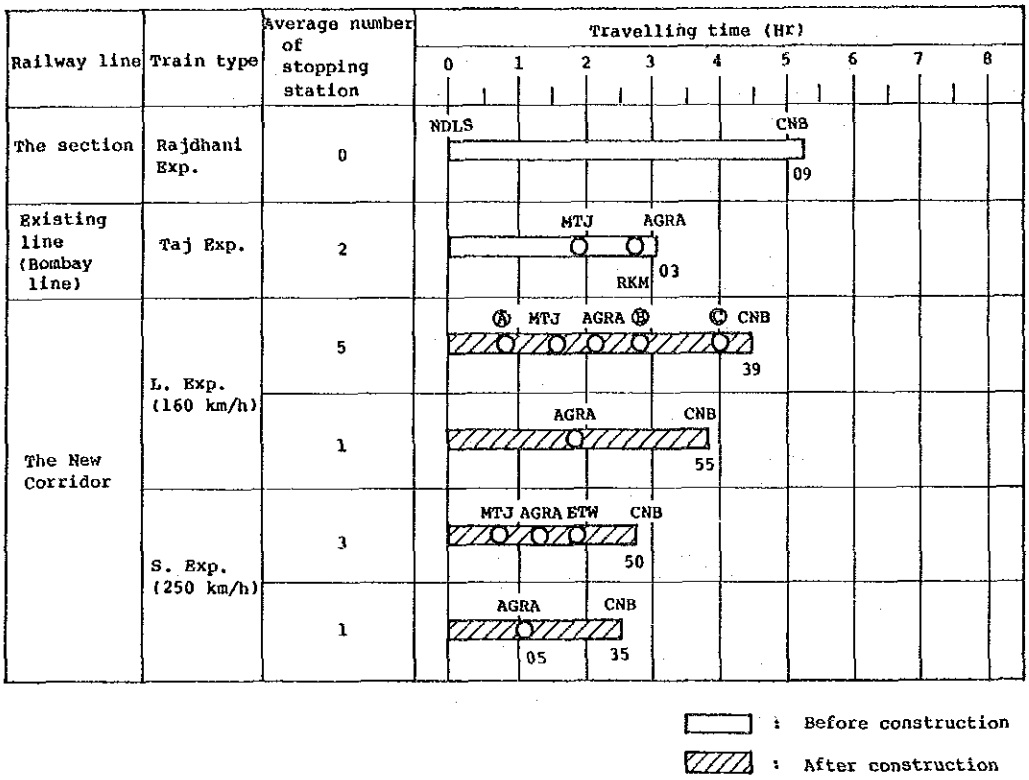


Fig. 6-5 Travelling Time (The New Corridor)

(4) Rolling stock

Particulars of Super Exp. train are proposed as follows:

Table 6-2 Rolling Stock Plan (The New Corridor)

Item			Contents
Train formation			6 M 10 T
Carring capacity (passenger/train)			1,560
Train length			400
Rated power	(KW)		7,920
Axle weigh	(ton)	M	15
		T	12.4
Acceleration	(m/s^2) (at 5 km/h)		0.34
Deceleration	(m/s^2)		0.63

a. To attain the above train performance, such new technologies are introduced as:

- 3 phase asynchronous motor
- Regenerative brake
- Eddy current brake
- Disc brake
- Flexible coupling for power transmission
- Bolsterless type bogie
- Light alloy body
- Automatic train control (ATC)

b. As a result of economical comparison made for 6 M 10 T and 2 M 14 T (push-pull system) trains, in terms of cost per passenger, both systems are almost comparable in procurement and maintenance costs, but as for track maintenance cost, 6 M 10 T type is more economical due to its lighter axle weight and smaller passing tonnage. From viewpoint of train running performance, both systems are adoptable.

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

(5) Track and structure

a. Railway structure

Embankment	412 km	(Min. height of 3.5 m)
Elevated track ...	17 km	(Agra area : 2 km Kanpur area : 15 km)
Joint use of existing track	21 km	(New Delhi-Tuglakabad : 19 km (Agra area : 2 km)

b. Track structure

Rail	60 Kg, CWR
Sleeper	PRC, 1720/km
Fastening	Double elastic fastening
Ballast	Crushed stone 30 cm or more depth
Turnout	Turnout with movable nose

. Yamuna River Bridge of 500 m length is constructed at Agra area.

. Passenger corridor connecting stations of the New Corridor and the conventional stations are constructed at New Mathura, New Agra and New Kanpur.

. Agricultural road crossings are provided approximately at every 500 m in the embankment area.

(6) Signalling and telecommunications

a. Signalling

Automatic train control (ATC)
Solid-state interlocking device
Centralized traffic control (CTC)
AF non-insulated track circuit

b. Telecommunication

Fibre optics system
Train radio
Telephone (Dispatcher, Automatic Exchange, Omnibus, etc.)
Teleprinter & Faximile

. In view of high speed train operation at 250 km, ATC incorporated with cab signal system is employed.
. CTC centre will be located at Agra.
. Trunk transmission line will be of dual system composed of optical fibre and SHF micro-wave links; the latter will be constructed by separate project.

(7) Electrification

a. Power supply system

Auto-transformer (AT) system	25 KV x 2
Power substation (SS)	6 SS
	60-80 M VA
	2 banks
	70-90 km interval
AT	5 M VA
	13-18 km interval
Sectioning post (SP)	between SS
Sub-sectioning post (SSP)	between SS and SP

b. OHE system

High tension compound catenary system

AT feeder wire	ACSR 320 mm^2
Catenary wire	ST 148 mm^2
Auxiliary catenary wire	Cu 130 mm^2
Contact wire	Hard drawn copper 150 mm^2
Max. span length	60 m
Current carring capacity	920 A

AT feeding system is adopted, for it can supply a large electric power with the least interference to telecommunication lines and with the minimum construction cost.

In view of high train speed, high tension compound catenary system is adopted.

(8) Investment cost

a. Initial investment

Table 6-3 Investment for Ground Facilities

(10^6Rs)

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

Table 6-4 Investment for Rolling Stock

(10^6Rs)

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

b. Additional investment for rolling stock (local currency)

Table 6-5 Additional Investment for Rolling Stock

(10^6Rs)

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

(9) Implementation schedule

Table 6-6 Implementation Schedule (The New Corridor)

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

7. Economic and Financial Analysis

(1) Cases to be analyzed

Case A: With ..... Upgrading the existing Delhi-Kanpur Section in 1991
Without ... No project

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

Case B: With ..... Constructing the New Corridor in 2000 between Delhi and Kanpur after upgrading the Section in 1991
Without ... Upgrading project in 1991

(Case B is set up to analyse the feasibility of the New Corridor construction project which assumes prior implementation of the Upgrading project.)

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

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

(2) EIRR/FIRR

Economic Internal Rate of Return (EIRR) and Financial Internal Rate of Return (FIRR) are shown in Table 7-1.

In case A, and Case B and C of base fare level, EIRRs surpass the opportunity cost of capital in India (estimated to be about 12%), and FIRRs are higher than the interest rate of 8.5% for funds from the Government Budget.

Table 7-1 EIRR/FIRR for Each Project Case

Case	Fare level* (%)	EIRR (%)	FIRR (%)	Project life (year)
A		42.62	25.79	37 (1988-2024)
B	0	26.76	7.47	37 (1988-2024)
	25	24.09	9.86	
	50	19.91	9.97	
	75	16.65	8.26	
	100	14.96	6.75	
C	0	37.28	16.81	37 (1988-2024)
	25	36.08	18.00	
	50	34.38	18.12	
	75	33.16	17.48	
	100	32.59	16.93	

Note: (1) "Fare level (%)" means that passenger fare level of the Super Exp. train of the New Corridor is set at higher level by 0, 25, 50, 75, or 100% than that of 2nd class Exp./Mail train of the Section.

(2) Among the five fare levels, 25% is set as a base fare level.

In calculating EIRR, investment/operating economic costs for railway to carry diverted/induced traffic volume and those for other transport modes (bus, truck and airplane) to carry the traffic volume to be diverted to the railway, and the related passenger-time-saving benefit are analysed.

In calculating FIRR, revenue and investment/operating costs due to diverted/induced railway traffic volume are calculated in terms of financial cost.

In Case B and C, the lower the fare level of the Super Exp. train of the New Corridor, the higher the EIRR figure, because cheaper fare will naturally attract more passengers to the New Corridor. On the other hand, FIRR is the highest when the fare is set at the level of 50%.

At the base fare level, EIRR/FIRR turn out extremely high in all cases; the highest in Case A, next Case C, then Case B.

(3) Net cash flow

To further examine the financial viability of the projects, net cash flow of Case A and that of Case B and C at base fare level are calculated for four financial plans shown in Table 7-2 and 7-3.

Table 7-2 Financing Plan

Currency / Plan	Foreign currency portion	Local currency portion
1.	Government to Government Borrowing	Goverment Budget
2.	Government to Government Borrowing	Goverment Budget (50%) Domestic Rupee Borrowing (50%)
3.	Official overseas Borrowing	Government Budget
4.	Official overseas Borrowing	Government Budget (50%) Domestic Rupee Borrowing (50%)

Table 7-3 Terms and Conditions of each Financing Source

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

Study results on net cash flow of Case A, and Cases B and C at base fare level for the various financing plans are as shown in Table 7-4 and 7-5.

Table 7-4 The Year when Net Cash Flow Turns into Black Figure and the Accumulated Deficit by Year

(million Rs)

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

Table 7-5 The Year when Accumulated Net Cash Flow Turns into Black Figure

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

According to the study result, for all project cases net cash flow will turn into the black within 2-4 years, and the accumulated net cash flow turns into black figure within 2-6 years after completion of the projects, excepting the case B under financing plan of 2 and 4, where 50% of the local currency portion resorts to domestic Rupee borrowing.

(4) Sensitivity analysis

Table 7-6 Sensitivity Analysis Result on EIRR

(%)

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

Table 7-7 Sensitivity Analysis Result on FIRR

(%)

Condition \ Case		A	B	C
	Base case*	25.79	9.86	18.00
a	10% revenue reduction	23.59	8.34	15.93
b	20% revenue reduction	21.23	6.67	13.74
c	50% revenue reduction	12.61	———	5.99
d	10% cost overrun	24.12	8.71	16.40
e	a + d	22.02	7.23	14.44
f	Extension of contruction period by 2 years	28.79	9.60	19.55

* Fare level of the New Corridor is 25%.

In consideration of possible adverse impacts in the future caused by such factors as heavy drought, upgrading of the highway/airway services in the study area as well as insufficient track capacity of the adjacent railway sections, sensitivity analysis is conducted for such factors as deviation of diverted traffic volume, investment cost, construction term and passenger time value.

In Case A and C, viability of the projects is proved for all deviated conditions excepting 50% revenue reduction in Case C.

In particular, upgrading project (Case A) shows a high margin of viability for even such a large deviation as reduction in diverted traffic volume by 50% or in revenue by 50%, which might occur in case the track capacity of the adjacent railway sections (i.e., railway networks of the Delhi Area and the Kanpur-Howrah Section) will not be able to meet the increased traffic demand in the future.

8. Conclusion and Recommendations

(1) Conclusion

The study result shows that it is technically feasible to improve the transport capacity (approximately 2 times) and train speed (max. 160 km/h) of the existing Ghaziabad - Kanpur Section, and to operate high speed trains at 250 km/h on the New Corridor. It is also proved that these projects will greatly contribute to the economic development of India, and that they are also financially viable for the Indian Railway.

Moreover, implementation of these projects will bring about various difficult-to-quantify benefits such as mitigation of road traffic accident/air pollution, promotion of related industries/job opportunity, and development of regional cities.

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

(2) Recommendations

1) Harmonious upgrading of the adjacent railway sections

In order to fully utilize the upgraded railway transportation capability on the Delhi (Ghaziabad) - Kanpur section, harmonious upgrading of the adjacent railway sections, i.e. the Kanpur - Howrah section and the railway networks of the Delhi area is prerequisite. Especially, in view of the practically saturated traffic conditions, immediate improvement of the railway networks in the Delhi Area is highly recommended.

2) Training

It is recommended that the training be provided on an expanded and long-term basis in line with implementation of the project to endow related employees adequate knowledge, skill and discipline required to properly operate/maintain the upgraded railway system.

3) Maintenance

To cope with the sharp increase in traffic density and train speed on the upgraded railway Section and the New Corridor, it is recommended to further develop the efficiency of maintenance work through mechanization and better maintenance control system.

4) Manufacturing technology

This plan is prepared with the policy of maximum use of domestic products. In view of the introduction of various new technologies, development of high-tech products and their quality control in particular is expected.

5) Further study of the New Corridor

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

ANNEX

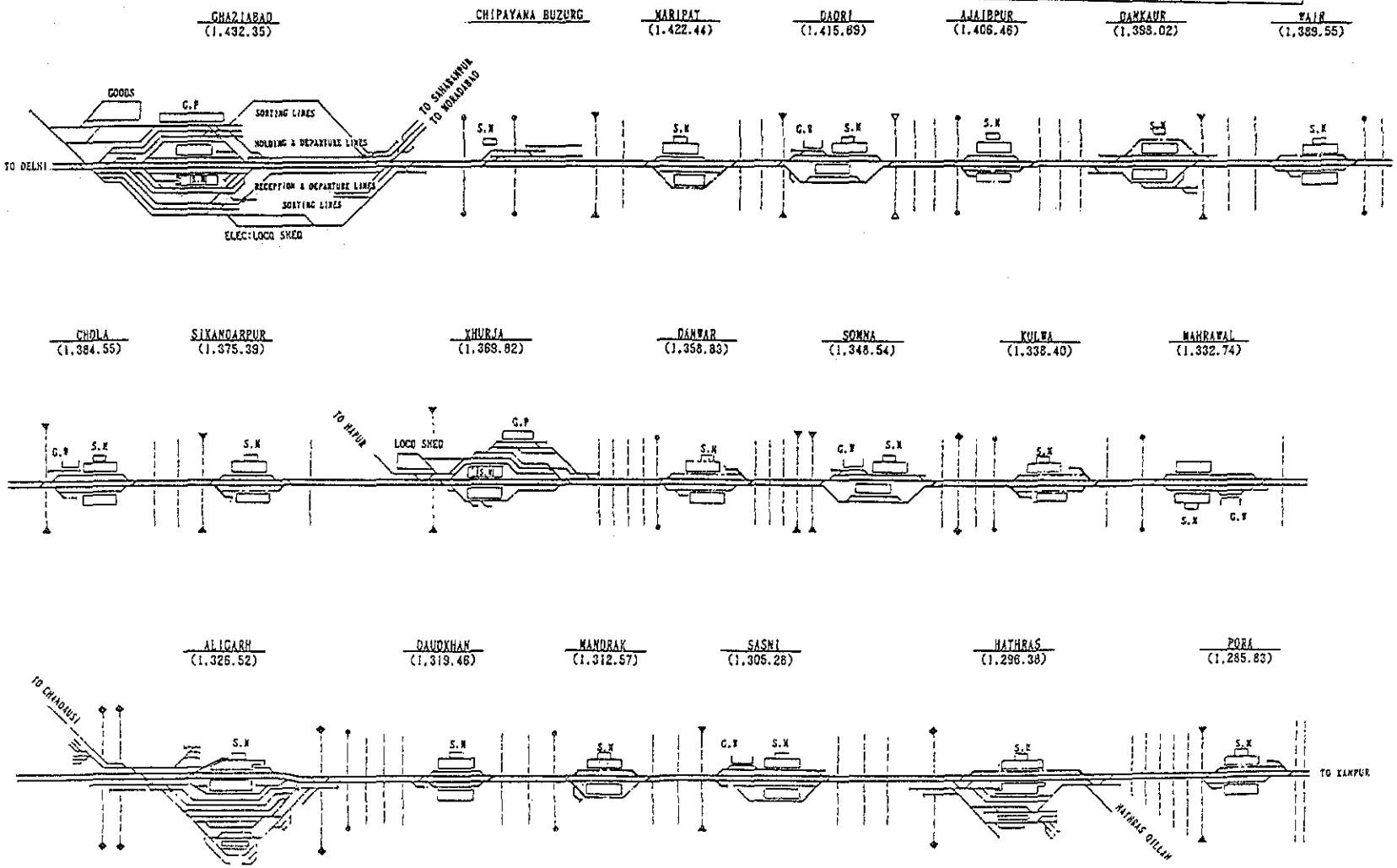
Annex 1-1 Railway Diagram of the Section (in 1990)

(Ghaziabad - Pore)

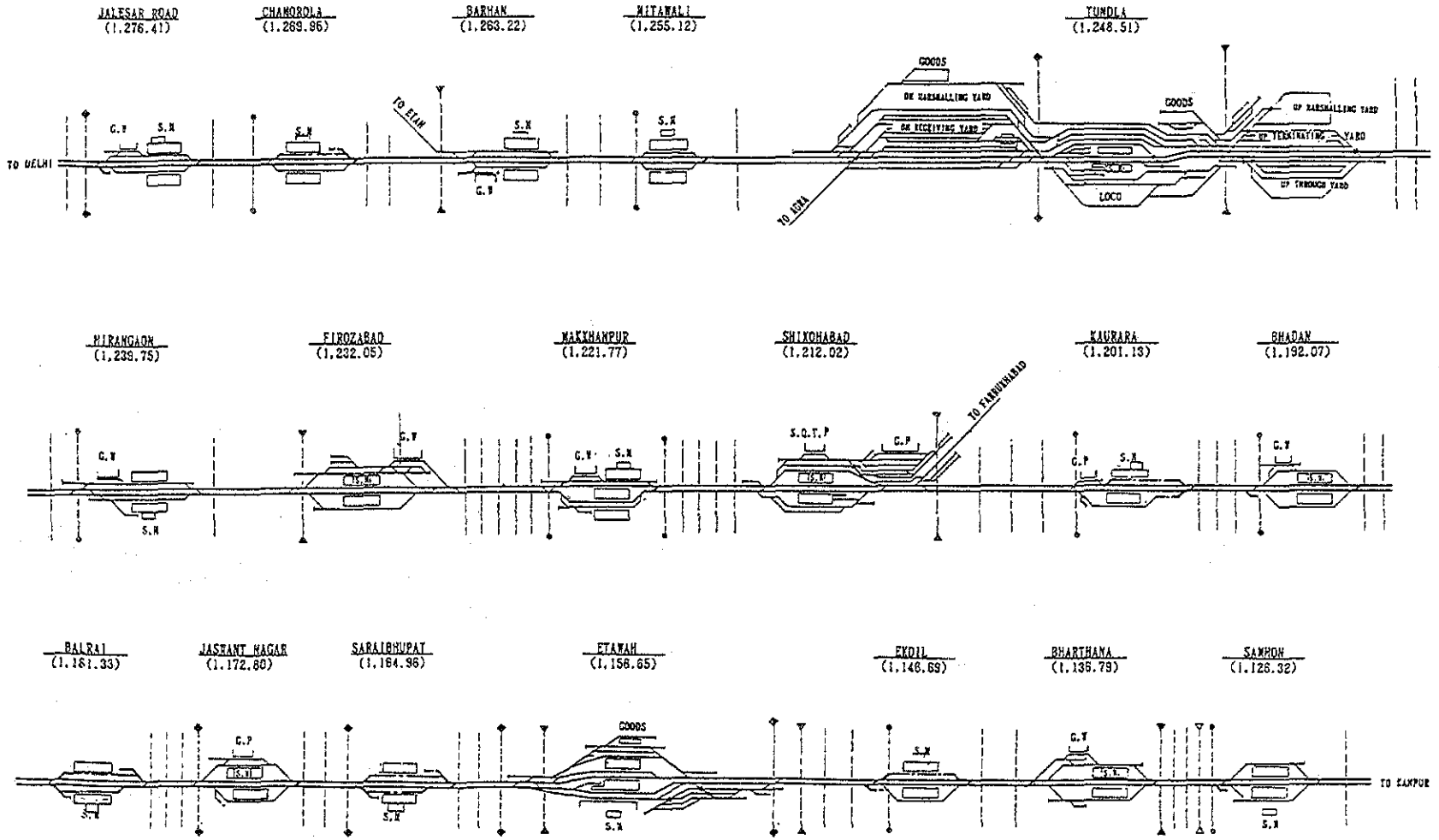
Legend

- Planned in the 7th Five Year Plan
- S.M Station Masters Room
- G.W Goods wharf
- G.P Goods platform

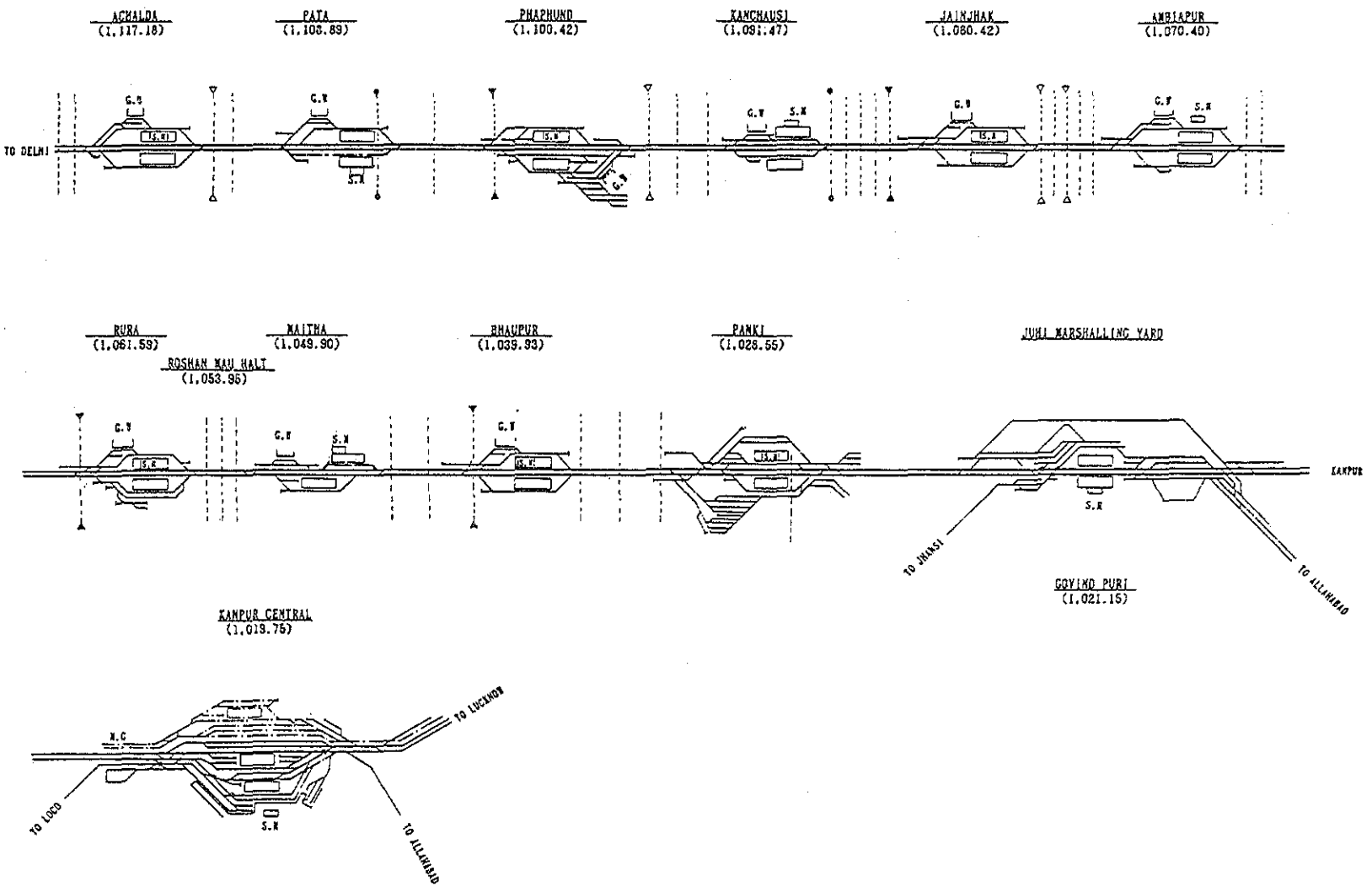
Class \ Level-crossing	Barrier without inter locking	Barrier interlocked with gate signal
A	◇---------◇	◁---------▷
B	▷---------◁	▶---------◀
C	---------	●---------●



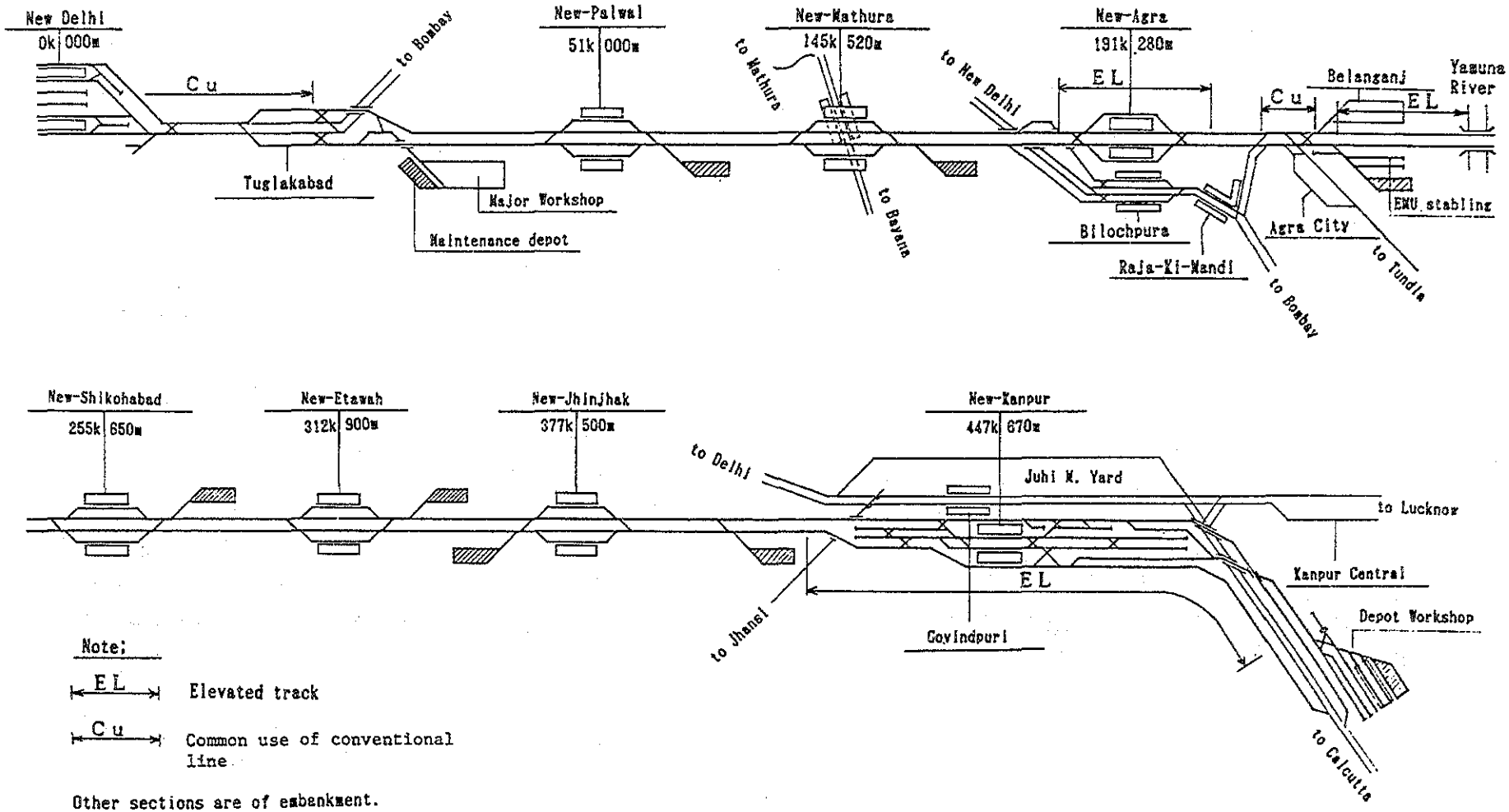
Annex 1-2 (Jalesar road - Samhon)



Annex 1-3 (Achalda - Kanpur)



Annex 2 Track Diagram of the New Corridor



Note;

EL ⟷ Elevated track

Cu ⟷ Common use of conventional line

Other sections are of embankment.

Annex 3 Number of Rolling Stock to be Acquired

Type	Item	Project: Upgrading the Section			New Corridor Construction																							Note
	Fare level (%)	—			0	25	50	75	100	0	25	50	75	100	0	25	50	75	100	0	25	50	75	100	0	25	50	75	100	
	Period	1986/1990	1991/1995	1996/2000	1996/2000					2001/2005					2006/2010					2011/2014					2016/	2016/	2016/	2016/2022	2016/2024	
EL	L. Express	(0) 3	1	2	0	1	3	5	5	0	1	2	2	2	0	1	2	3	3	0	0	2	3	3	0	0	0	7	6	New EL x 2
	Ex./Mail	(5) 6	10	21	Δ34	Δ27	Δ24	Δ24	Δ24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	WAP1
	Local	(2) 2	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	-	-	-	-	-	-	-	-	-	-	WAM4
	Freight fast	(0) 22	11	8	0	0	0	0	0	14	14	14	14	14	11	11	11	11	11	-	-	-	-	-	-	-	-	-	-	WAG6
	Freight ordinary	(1) 1	0	0	0	0	0	0	0	7	7	7	7	7	15	15	15	15	15	-	-	-	-	-	-	-	-	-	-	WAG5
	Total No.	(8) 34	22	31	0	1	3	5	5	21	22	23	23	23	27	28	26	29	29	0	0	2	3	3	0	0	0	7	6	
PC	L. Express	(0) 3	1	2	0	1	3	5	5	0	1	2	2	2	0	1	2	3	3	0	0	2	3	3	0	0	0	7	6	. Showing No. of formations . L. Exp. & Local: 18 coaches/formation . Exp./Mail: 19.5 coaches/formation
	Ex./Mail	(6) 6	10	21	Δ34	Δ27	Δ24	Δ24	Δ24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Local	(2) 2	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	-	-	-	-	-	-	-	-	-	-	
	Total No.	(8) 11	11	23	0	1	3	5	5	0	1	2	2	2	1	2	2	3	3	0	0	2	3	3	0	0	0	7	6	
FW	Fast	(11) 22	11	8	0	0	0	0	0	14	14	14	14	14	11	11	11	11	11	-	-	-	-	-	-	-	-	-	-	. Showing No. of formations . Fast: 56 wagons/formation . Ordinary: 28 wagons/formation
	Ordinary	(1) 1	0	0	0	0	0	0	0	7	7	7	7	7	15	15	15	15	15	-	-	-	-	-	-	-	-	-	-	
	Total No.	(12) 23	11	8	0	0	0	0	0	21	21	21	21	21	26	26	26	26	26	-	-	-	-	-	-	-	-	-	-	
EMU	Super Exp.	-	-	-	((5)) 40	((5)) 29	((5)) 19	((5)) 11	((5)) 8	7	7	5	3	2	0	8	6	4	2	0	0	7	5	3	0	0	1	9	8	. Showing No. of formations . 16 coaches/formation
	(ATC for L. Exp.)	-	-	-	6	7	9	11	11	0	1	2	2	2	0	1	2	3	3	0	0	2	3	3	0	0	0	7	6	

The number in parenthesis are those included in the 7th 5-year Plan.
The number in double parenthesis are those to be imported.
The number attached with triangle are those to be transferred to the other railway section.

Annex 4 Major Ground Facilities to be Introduced or Improved to Upgrade the Section

Classification	Item	Quantity	Note
Land	. Modification of station yards, etc.	17,100 m^2	Kanpur, Tundla, Ghaziabad
Track & Structure	. Track security fence	573 Km	
	. Bridge (replacement)	2	Multiple-span bridge, fly-over bridge
	. Platform	3	Kanpur, Etawah, Aligah
	. Security fence on platforms	37	
	. Track	36 Km	Track layout modification
	. Track (improvement)	17 Km	Cant: 70 curves Transition curves: 34
	. Turnout	694	Main track: 333 Track layout modification: 361
Signalling & Telecommunication	. Automatic block	49	Including AF track circuit, signal, cable, etc.
	. Solid-state interlocking device	38 stations	
	. Automatic level-crossing protection device	166 level crossings	Fixed barrier-closing time control
	. AWS	840	Transponder type
	. CTC	50 stations	Control center is located at Tundla
	. Automatic train approach Warning device	58	
Electrificaiton	. Automatic circuit breaker	26	13 SS x 2
	. Automatic circuit reclosing system	7 SS	
	. Switch board for feeding	26	13 SS x 2
	. OHE (modification)	930 Km	Tension strengthening, etc.
	. OHE	53 Km	Track layout modification

Annex 5 Major Ground Facilities of the New Corridor

Classification	Item	Quantity	Note
Land	. Track, station, etc.	12.8 Km^2	
Track & Structure	. Embankment	412 Km	3.5 m height
	. Bridge	0.5 Km	
	. Elevated track	17 Km	Agra 2 Km, Kanpur 15 Km
	. Track	100 Km	(track-length)
	. Station	8 stations	
	. Maintenance depot	9	
	. Rolling stock workshop/ depot	2	
	. Solid state interlocking device	11 Stations	
	. ATC	1000 Km	Max. 260 Km/h.
	. CTC	11 stations	Dispatcher tel.
	. Train radio	37 trains	Space radio type
	. Transmission line	450 Km	Fibre optics, metalic cable, etc.
	. Telecommunication equipment		Carrier terminal, repeater. telephone, teleprinter, etc.
	. Power feeding line	73 Km	220 KV: 20 Km 132 KV: 53 Km
	. SS	6	
	. SP	6	
	. SSP	10	
	. CC	1	
	. AT	74	
	. OHE	1000 Km	(Track length)

Annex 6-1 Summary of Cash Flow Analysis

Case (A)

(Unit: Million Rs)

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

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

Annex 6-2 Summary of Cash Flow Analysis

Case (B)

(Unit: Million Rs)

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

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

Annex 6-3 Summary of Cash Flow Analysis

Case (C)

(Unit: Million Rs)

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

Note: Figures in parentheses are accumulated amounts.

Figures with Δ means deficit value.