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No. 7

REPORT

FOR

THE FEASIBILITY STUDY

ON

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

IN

INDIA

APPENDIX

DECEMBER 1987

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

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1-1 Elasticity of Traffic Volume

Trend of Passenger Traffic

Year	Population (Million)	GNP (Crores.Rs.)	Passenger-km (Billion)	Average lead (km)	No. of passengers (Billion x α)
1950	360.950	17,469	106.9	68.8	1,554
1955	390.397	20,190	118.4	69.6	1,701
1960	430.575	23,802	164.3	72.1	2,279
1965	479.005	30,399	240.6	74.4	3,234
1968	512.318	31,590	303.0	77.5	4,125
1973	572.999	36,629	416.2	88.5	4,703
1977	626.586	43,076	565.5	87.1	6,493
1980	670.040	47,180	726.6	103.9	6,993
1981	685.185	50,824	869.9	107.8	8,069
1882	700.672	53,166	945.2	111.4	8,485
1983	716.507	54,084	969.3	121.3	7,991
1984	732.628	58,112	1,059.7	125.8	8,424

Source: Surface Transport and Year Book of Railway

1971 price
Ln(NP*α) = -7.260 + 1.493*Ln (GNP) Y=0.9946
NP: No. of Passengers
NP=C*GNP^1.493 Elasticity=1.493
C, α: Constant

Passenger-km includes the road traffic volume
Average lead is the data of non-suburban traffic by rail.
Y: Correlation coefficient

Trend of Freight Traffic

Year	Population (Million)	GNP (Crores.Rs.)	Freight Ton-km	Average lead (km)	Traffic volume (Billion*α)
1950	360.950	17,469	56.2	513.0	109.55
1955	390.397	20,190	70.1	541.0	129.57
1960	430.575	23,802	108.3	603.0	179.60
1965	479.005	30,399	147.4	611.0	241.24
1968	512.318	31,590	171.4	633.0	270.77
1973	572.999	36,629	211.8	675.0	313.78
1977	626.586	43,076	260.2	713.0	364.94
1980	670.040	47,180	295.0	754.0	391.25
1981	685.185	50,824	319.7	743.0	430.28
1882	700.672	53,166	357.2	733.0	487.31
1983	716.507	54,084	371.3	734.0	505.86
1984	732.628	58,112	386.5	730.0	529.45

Source: Surface Transport and Year Book of Railway

1971 price
Ln(τ*α) = -8062 + 1.3089*Ln (GNP) Y=0.992
τ: Freight-ton transported.
τ=C*GNP^1.3089 Elasticity=1.3089
C, α: Constant

The ton-km includes the road traffic volume.
Average lead is the data by rail traffic.
Y: Correlation coefficient

1-1 Continued

Year	GNP per Capita (Rs)(1971 price)	No. of Trips per Capita (Billion/year*α)
1950	483.97	4.305
1955	517.17	4.357
1960	552.80	5.293
1965	634.63	6.751
1968	616.61	8.052
1973	639.25	8.208
1977	687.47	10.363
1980	704.14	10.436
1981	741.76	11.776
1982	758.79	12.110
1983	754.83	11.153
1984	793.20	11.498

LN (No. of Trips per Capita)=-13.134+2.352*LN (GNP per Capita)

γ=0.9774

NP=NPo*(No. of Trips per Capita)

=NpO*C*(GNP per Capita)^2.352

Elasticity=2.352

γ : Correlation coefficient

C,α : Constant

1-2 Passenger Transport Time and Fare between Each Zone

(1) Transport time data

Item / Mode	Access/ Egress time (min.)	Waiting time, Check-in time (min.)	Commercial speed (km/h)
Railway	100	20	Before upgrading 65 After upgrading 70 New Corridor 170/Max. 250 115/Max. 160
Bus	100	20	40 km/h
Aircraft	90	60	500 km/h

(2) Passenger fare data

	Access/ Egress cost (Rs)	Travelling cost (Rs/km)
Railway	(Bus) 7.0	Conventional lines 0.11 Rs/km Long Distance Express 0.36 Rs/km New Corridor 0% up ∿ 100% up
Bus	(Bus) 7.0	0.09 Rs/km
Aircraft	(Taxi) 40	1.00 Rs/km

(3) Time value

1985 5.0 Rs/h
2000 7.5 Rs/h

Since the future growth of the passenger's time value is more important than its value itself in determining the modal split, the time value for business travelers accounting for a major portion of train passenger is adopted as the representative time value.

And it is assumed that the time value distribution will change little from the present pattern in the future and that growth of the its average value will be proportional to the increase of GDP per capita.

1-3 Future OD Table of Railway (1)

Rail Passenger OD Table at Year 2000 without Project (Passenger/day)

ZONE No.		1 DELHI	2 GHAZIABAD	3 BULANDSHAR	4 FARIDABAD	5 ALIGARH	6 MATHURA	7 AGRA	8 ETAH	9 ETAWAH	10 KANPUR	11 LUCKNOW	12 HADORI	13 BAREILLY	14 MEERUT	15 HARYANA	16 RAJASTHAN	17 MADHYA	18 BIHAR	TOTAL
1	DELHI	0	18,570	7,611	11,192	6,514	5,435	5,998	968	1,446	6,735	8,034	6,122	9,015	11,672	0	6,153	10,000	7,297	122,762
2	GHAZIABAD	18,570	0	1,564	1,484	894	458	641	87	151	532	1,606	1,217	2,440	2,321	0	932	1,464	1,803	36,163
3	BULANDSHAR	7,611	1,564	0	1,842	1,711	858	1,556	75	169	484	721	488	660	869	1,641	431	825	955	22,462
4	FARIDABAD	11,192	1,484	1,842	0	962	646	649	67	86	342	766	592	755	962	0	568	1,662	918	23,492
5	ALIGARH	6,514	894	1,711	962	0	2,909	1,785	125	237	352	1,129	798	1,089	1,211	2,415	701	1,284	1,521	25,639
6	MATHURA	5,435	458	858	646	2,909	0	1,791	140	184	437	638	450	608	611	2,374	627	2,035	979	21,180
7	AGRA	5,998	641	1,556	649	1,785	1,791	0	873	780	1,692	972	977	1,074	1,316	5,737	1,493	5,030	1,323	33,687
8	ETAH	968	87	75	67	125	140	873	0	301	474	519	419	414	286	991	294	573	674	7,280
9	ETAWAH	1,446	151	169	86	237	184	780	301	0	2,029	1,273	828	692	512	1,817	545	1,107	1,465	13,621
10	KANPUR	6,735	532	484	342	352	437	1,692	474	2,029	0	5,762	2,934	2,136	1,284	4,056	1,214	2,632	14,349	47,445
11	LUCKNOW	8,034	1,606	721	766	1,129	638	972	519	1,273	5,762	0	0	0	0	0	0	0	0	21,419
12	HADORI	6,122	1,217	488	592	798	450	977	419	828	2,934	0	0	0	0	0	0	0	0	14,825
13	BAREILLY	9,015	2,440	660	755	1,089	608	1,074	414	692	2,136	0	0	0	0	0	0	0	0	18,883
14	MEERUT	11,672	2,321	869	962	1,211	611	1,316	286	512	1,284	0	0	0	0	0	0	0	0	21,043
15	HARYANA	0	0	1,641	0	2,415	2,374	5,737	991	1,817	4,056	0	0	0	0	0	0	0	3,309	22,340
16	RAJASTHAN	6,153	932	431	568	701	627	1,493	294	545	1,214	0	0	0	0	0	0	0	0	12,957
17	MADHYA	10,000	1,464	825	1,662	1,284	2,035	5,030	573	1,107	2,632	0	0	0	0	0	0	0	0	26,613
18	BIHAR	7,297	1,803	955	918	1,521	979	1,323	674	1,465	14,349	0	0	0	0	3,309	0	0	0	34,594
	TOTAL	122,762	36,163	22,462	23,492	25,639	21,180	33,687	7,280	13,621	47,445	21,419	14,825	18,883	21,043	22,340	12,957	26,613	34,594	526,407

Rail Passenger OD Table at Year 2000 with Upgrading the Section (Max. 160 km/h, Fare 0% up) (Passenger/day)

ZONE No.		1 DELHI	2 GHAZIABAD	3 BULANDSHAR	4 FARIDABAD	5 ALIGARH	6 MATHURA	7 AGRA	8 ETAH	9 ETAWAH	10 KANPUR	11 LUCKNOW	12 HADORI	13 BAREILLY	14 MEERUT	15 HARYANA	16 RAJASTHAN	17 MADHYA	18 BIHAR	TOTAL
1	DELHI	0	19,617	8,282	11,450	6,872	5,513	6,086	1,056	1,506	6,956	8,187	6,215	9,228	11,992	0	6,251	10,082	7,951	127,242
2	GHAZIABAD	19,617	0	1,679	1,496	927	463	643	94	153	551	1,618	1,224	2,484	2,360	0	938	1,472	1,843	37,562
3	BULANDSHAR	8,282	1,679	0	1,878	1,846	881	1,608	83	182	536	767	501	683	902	1,723	440	852	1,014	23,857
4	FARIDABAD	11,450	1,496	1,878	0	966	646	649	69	87	346	766	593	756	963	0	568	1,662	923	23,817
5	ALIGARH	6,872	927	1,846	966	0	2,950	1,830	137	252	383	1,178	803	1,108	1,249	2,529	711	1,312	1,588	26,641
6	MATHURA	5,513	463	881	646	2,950	0	1,791	144	190	462	653	450	609	613	2,374	627	2,035	1,002	21,405
7	AGRA	6,086	643	1,608	649	1,830	1,791	0	904	807	1,773	1,004	978	1,076	1,320	5,737	1,493	5,030	1,366	34,095
8	ETAH	1,056	94	83	69	137	144	904	0	328	524	556	428	424	305	1,084	303	591	720	7,750
9	ETAWAH	1,506	153	182	87	252	190	807	328	0	2,179	1,342	850	703	538	1,986	559	1,153	1,538	14,354
10	KANPUR	6,956	551	536	346	383	462	1,773	524	2,179	0	5,950	3,010	2,181	1,333	4,434	1,240	2,688	14,885	49,431
11	LUCKNOW	8,187	1,618	767	766	1,178	653	1,004	556	1,342	5,950	0	0	0	0	0	0	0	0	22,020
12	HADORI	6,215	1,224	501	593	803	450	978	428	850	3,010	0	0	0	0	0	0	0	0	15,051
13	BAREILLY	9,228	2,484	683	756	1,108	609	1,076	424	703	2,181	0	0	0	0	0	0	0	0	19,252
14	MEERUT	11,991	2,360	902	963	1,249	613	1,320	305	538	1,333	0	0	0	0	0	0	0	0	21,574
15	HARYANA	0	0	1,723	0	2,529	2,374	5,737	1,084	1,986	4,434	0	0	0	0	0	0	0	3,616	23,483
16	RAJASTHAN	6,251	938	440	568	711	627	1,493	303	559	1,240	0	0	0	0	0	0	0	0	13,130
17	JHANSI	10,082	1,472	852	1,662	1,312	2,035	5,030	591	1,153	2,688	0	0	0	0	0	0	0	0	36,447
18	BIHAR	7,951	1,843	1,014	923	1,588	1,002	1,366	720	1,538	14,885	0	0	0	0	3,616	0	0	0	36,447
	TOTAL	127,242	37,562	23,857	23,817	26,641	21,405	34,095	7,750	14,354	49,431	22,020	15,051	19,252	21,574	23,483	13,130	26,879	36,447	543,989

1-4 Future OD Table of Railway (2)

Rail Passenger OD Table at Year 2000 with New Corridor Construction and with Upgrading the Section (Max. 250 km/h, Fare 0% up) (Passenger/day)

ZONE No.		1 DELHI	2 GHAZIABAD	3 BULANDSH	4 FARIDABAD	5 ALIGARH	6 MATHURA	7 AGRA	8 ETAH	9 ETAWAH	10 KANPUR	11 LUCKNOW	12 HADORI	13 BAREILLY	14 MEERUT	15 HARYANA	16 RAJASTHAN	17 MADHYA	18 BIHAR	TOTAL
1	DELHI	0	19,617	8,232	11,450	6,872	6,688	7,731	1,446	1,904	8,099	12,257	6,215	9,228	11,991	0	6,251	12,109	15,139	145,278
2	GHAZIABAD	19,617	0	1,679	1,496	927	514	665	94	163	636	1,876	1,224	2,484	2,360	0	939	1,584	2,083	38,340
3	BULANDSHAR	8,282	1,679	0	1,878	1,846	1,127	1,608	83	182	536	767	501	683	902	1,723	440	852	1,014	24,103
4	FARIDABAD	11,450	1,496	1,878	0	966	646	649	69	98	379	820	593	756	963	0	568	1,662	998	23,990
5	ALIGARH	6,872	927	1,846	966	0	3,247	1,830	137	252	383	1,178	803	1,108	1,249	2,529	711	1,312	1,588	26,938
6	MATHURA	6,608	514	1,127	646	3,247	0	2,234	226	355	981	1,126	506	754	652	2,374	627	2,128	1,706	25,891
7	AGRA	7,731	665	1,608	649	1,830	2,234	0	904	1,447	3,014	2,349	1,038	1,277	1,474	5,737	1,493	5,030	2,877	41,356
8	ETAH	1,446	94	83	69	137	226	904	0	328	524	556	428	424	305	1,084	303	591	720	8,222
9	ETAWAH	1,904	163	182	98	252	355	1,447	328	0	3,471	2,813	1,166	857	734	2,854	781	1,771	2,591	21,768
10	KANPUR	8,099	636	536	379	383	981	3,014	524	3,471	0	5,950	3,010	2,181	1,585	6,558	1,479	2,688	14,885	56,358
11	LUCKNOW	12,257	1,876	767	820	1,178	1,126	2,349	556	2,813	5,950	0	0	0	0	0	0	0	0	29,691
12	HADORI	6,215	1,224	501	593	803	506	1,038	428	1,166	3,010	0	0	0	0	0	0	0	0	15,484
13	BAREILLY	9,228	2,484	683	756	1,108	754	1,277	424	857	2,181	0	0	0	0	0	0	0	0	19,751
14	MEERUT	11,991	2,360	902	963	1,249	652	1,474	305	734	1,585	0	0	0	0	0	0	0	0	22,215
15	HARYANA	0	0	1,723	0	2,529	2,374	5,737	1,084	2,854	6,558	0	0	0	0	0	0	0	13,131	35,991
16	RAJASTHAN	6,251	939	440	568	711	627	1,493	303	781	1,479	0	0	0	0	0	0	0	0	13,591
17	MADHYA	12,109	1,584	852	1,662	1,312	2,128	5,030	591	1,771	2,688	0	0	0	0	0	0	0	0	29,728
18	BIHAR	15,139	2,083	1,014	998	1,588	1,706	2,877	720	2,591	14,885	0	0	0	0	13,131	0	0	0	56,734
	TOTAL	145,278	38,340	24,103	23,990	26,938	25,891	41,356	8,222	21,768	56,358	29,691	15,484	19,751	22,215	35,991	13,591	29,728	56,734	635,428

Rail Passenger OD Table at Year 2000 with New Corridor Construction and Upgrading the Section (Max. 250 km/h, Fare 25% up) (Passenger/day)

ZONE No.		1 DELHI	2 GHAZIABAD	3 BULANDSH	4 FARIDABAD	5 ALIGARH	6 MATHURA	7 AGRA	8 ETAH	9 ETAWAH	10 KANPUR	11 LUCKNOW	12 HADORI	13 BAREILLY	14 MEERUT	15 HARYANA	16 RAJASTHAN	17 MADHYA	18 BIHAR	TOTAL
1	DELHI	0	19,617	8,282	11,450	6,872	6,279	7,153	1,194	1,833	7,855	11,307	6,215	9,228	11,991	0	6,251	11,395	12,582	139,502
2	GHAZIABAD	19,617	0	1,679	1,496	927	491	656	94	159	598	1,763	1,224	2,484	2,360	0	938	1,550	1,982	38,018
3	BULANDSHAR	8,282	1,679	0	1,878	1,846	1,050	1,608	83	182	536	767	501	683	902	1,723	440	852	1,014	24,026
4	FARIDABAD	11,450	1,496	1,878	0	966	646	649	69	94	365	801	593	756	963	0	568	1,662	962	23,917
5	ALIGARH	6,872	927	1,846	966	0	3,115	1,830	137	252	383	1,178	803	1,108	1,249	2,529	711	1,312	1,588	26,805
6	MATHURA	6,279	491	1,050	646	3,115	0	2,078	210	335	880	1,076	487	751	613	2,374	627	2,100	1,596	24,708
7	AGRA	7,153	656	1,608	649	1,830	2,078	0	904	1,360	2,747	2,105	1,028	1,240	1,320	5,737	1,493	5,030	2,509	39,446
8	ETAH	1,194	94	83	69	137	210	904	0	328	524	556	428	424	305	1,084	303	591	720	7,955
9	ETAWAH	1,833	159	182	94	252	335	1,360	328	0	3,117	2,520	1,136	835	609	1,986	736	2,648	2,307	19,437
10	KANPUR	7,855	598	536	365	383	880	2,747	524	3,117	0	5,950	3,010	2,181	1,370	4,434	1,411	2,688	14,885	52,932
11	LUCKNOW	11,307	1,763	767	801	1,178	1,076	2,105	556	2,520	5,950	0	0	0	0	0	0	0	0	28,020
12	HADORI	6,215	1,224	501	593	803	487	1,028	428	1,136	3,010	0	0	0	0	0	0	0	0	15,425
13	BAREILLY	9,228	2,484	683	756	1,108	751	1,240	424	835	2,181	0	0	0	0	0	0	0	0	19,689
14	MEERUT	11,991	2,360	902	963	1,249	613	1,320	305	609	1,370	0	0	0	0	0	0	0	0	21,683
15	HARYANA	0	0	1,723	0	2,529	2,374	5,737	1,084	1,986	4,434	0	0	0	0	0	0	0	9,131	28,999
16	RAJASTHAN	6,251	938	440	568	711	627	1,493	303	736	1,411	0	0	0	0	0	0	0	0	13,478
17	MADHYA	11,395	1,550	852	1,662	1,312	2,100	5,030	591	1,648	2,688	0	0	0	0	0	0	0	0	28,330
18	BIHAR	12,582	1,982	1,014	962	1,588	1,596	2,509	720	2,307	14,885	0	0	0	0	9,131	0	0	0	49,277
	TOTAL	139,502	38,018	24,026	23,917	26,805	24,708	39,446	7,955	19,437	52,932	28,020	15,425	19,689	21,683	28,999	13,478	28,830	49,277	602,150

1-5 Future OD Table of Railway (3)

Rail Passenger OD Table at Year 2000 with New Corridor Construction and Upgrading the Section (Max. 250 km/h, Fare 50% up) (Passenger/day)

ZONE No.		1 DELHI	2 GHAZIABAD	3 BULANDSH	4 FARIDABAD	5 ALIGARH	6 MATHURA	7 AGRA	8 ETAH	9 ETAWAH	10 KANPUR	11 LUCKNOW	12 HADORI	13 BAREILLY	14 MEERUT	15 HARYAMA	16 RAJASTHAN	17 MADHYA	18 BIHAR	TOTAL
1	DELHI	0	19,617	8,282	11,450	6,872	5,804	6,443	1,056	1,714	7,347	9,505	6,215	9,228	11,991	0	6,251	10,667	9,540	131,980
2	GHAZIABAD	19,617	0	1,679	1,496	927	464	643	94	153	551	1,618	1,224	2,484	2,360	0	938	1,502	1,843	37,592
3	BULANDSHAR	8,282	1,679	0	1,878	1,846	963	1,608	83	182	536	767	501	683	902	1,723	440	852	1,104	23,939
4	FARIDABAD	11,450	1,496	1,878	0	966	646	649	69	87	346	766	593	756	963	0	568	1,662	923	23,817
5	ALIGARH	6,872	927	1,846	966	0	2,953	1,830	137	252	383	1,178	803	1,108	1,249	2,529	711	1,312	1,588	26,644
6	MATHURA	5,804	464	963	646	2,953	0	1,929	195	311	740	993	456	747	613	2,374	627	2,071	1,427	23,314
7	AGRA	6,443	643	1,608	649	1,830	1,929	0	904	1,263	2,396	1,795	1,012	1,191	1,320	5,737	1,493	5,030	2,070	37,312
8	ETAH	1,056	94	83	69	137	195	904	0	328	524	556	428	424	305	1,084	303	591	720	7,801
9	ETAWAH	1,714	153	182	87	252	311	1,263	328	0	2,749	2,216	1,100	796	538	1,986	686	1,515	2,017	17,893
10	KANPUR	7,347	551	536	346	383	740	2,396	524	2,749	0	5,950	3,010	2,181	1,333	4,434	1,312	2,688	14,885	51,363
11	LUCKNOW	9,505	1,618	767	766	1,178	993	1,795	556	2,216	5,950	0	0	0	0	0	0	0	0	25,344
12	HADORI	6,215	1,224	501	593	803	456	1,012	428	1,100	3,010	0	0	0	0	0	0	0	0	15,341
13	BAREILLY	9,228	2,484	683	756	1,108	747	1,191	424	796	2,181	0	0	0	0	0	0	0	0	19,597
14	MEERUT	11,991	2,360	902	963	1,249	613	1,320	305	538	1,333	0	0	0	0	0	0	0	0	21,574
15	HARYANA	0	0	1,723	0	2,529	2,347	5,737	1,084	1,986	4,434	0	0	0	0	0	0	0	5,235	25,102
16	RAJASTHAN	6,251	938	440	568	711	627	1,493	303	686	1,312	0	0	0	0	0	0	0	0	13,329
17	MADHYA	10,667	1,502	852	1,662	1,312	2,071	5,030	591	1,515	2,688	0	0	0	0	0	0	0	0	27,892
18	BIHAR	9,540	1,843	1,014	923	1,588	1,427	2,070	720	2,017	14,885	0	0	0	0	5,235	0	0	0	41,262
	TOTAL	131,980	37,592	23,939	23,817	26,644	23,314	37,312	7,801	17,893	51,363	25,344	15,341	19,597	21,574	25,102	13,329	27,892	41,262	571,098

Rail Passenger OD Table at Year 2000 with New Corridor Construction and with Upgrading the Section (Max. 250 km/h, Fare 75% up) (Passenger/day)

ZONE No.		1 DELHI	2 GHAZIABAD	3 BULANDSH	4 FARIDABAD	5 ALIGARH	6 MATHURA	7 AGRA	8 ETAH	9 ETAWAH	10 KANPUR	11 LUCKNOW	12 HADORI	13 BAREILLY	14 MEERUT	15 HARYANA	16 RAJASTHAN	17 MADHYA	18 BIHAR	TOTAL
1	DELHI	0	19,617	8,282	11,450	6,872	5,513	6,086	1,056	1,530	6,956	8,187	6,215	9,228	11,991	0	6,251	10,323	8,072	127,627
2	GHAZIABAD	19,617	0	1,679	1,496	927	463	643	94	153	551	1,618	1,224	2,484	2,360	0	938	1,472	1,843	37,562
3	BULANDSHAR	8,282	1,679	0	1,878	1,846	881	1,608	83	182	536	767	501	683	902	1,723	440	852	1,014	23,857
4	FARIDABAD	11,450	1,496	1,878	0	966	646	649	69	87	346	766	593	756	963	0	568	1,662	923	23,817
5	ALIGARH	6,872	927	1,846	966	0	2,950	1,830	137	252	383	1,178	803	1,108	1,249	2,529	711	1,312	1,588	26,641
6	MATHURA	5,513	463	881	646	2,950	0	1,791	181	282	574	872	450	742	613	2,374	627	2,039	1,197	22,196
7	AGRA	6,086	643	1,608	649	1,830	1,791	0	904	1,160	1,976	1,443	986	1,124	1,320	5,737	1,493	5,030	1,605	35,385
8	ETAH	1,056	94	83	69	137	181	904	0	328	524	556	428	424	305	1,084	303	591	720	7,787
9	ETAWAH	1,530	153	182	87	252	282	1,160	328	0	2,380	1,914	1,055	734	538	1,986	632	1,375	1,730	16,318
10	KANPUR	6,956	551	536	346	383	574	1,976	524	2,380	0	5,950	3,010	2,181	1,333	4,434	1,240	2,688	14,885	49,946
11	LUCKNOW	8,187	1,618	767	766	1,178	872	1,443	556	1,914	5,950	0	0	0	0	0	0	0	0	23,250
12	HADORI	6,215	1,224	501	593	803	450	986	428	1,055	3,010	0	0	0	0	0	0	0	0	15,264
13	BAREILLY	9,228	2,484	683	756	1,108	742	1,124	424	734	2,181	0	0	0	0	0	0	0	0	19,462
14	MEERUT	11,991	2,360	902	963	1,249	613	1,320	305	538	1,333	0	0	0	0	0	0	0	0	21,574
15	HARYANA	0	0	1,723	0	2,529	2,374	5,737	1,084	1,986	4,434	0	0	0	0	0	0	0	3,616	23,483
16	RAJASTHAN	6,251	938	440	568	711	627	1,493	303	632	1,240	0	0	0	0	0	0	0	0	13,203
17	MADHYA	10,323	1,472	852	1,662	1,312	2,039	5,030	591	1,375	2,688	0	0	0	0	0	0	0	0	27,347
18	BIHAR	8,072	1,843	1,014	923	1,588	1,197	1,605	720	1,730	14,885	0	0	0	0	3,616	0	0	0	37,193
	TOTAL	127,627	37,562	23,857	23,817	26,641	22,196	35,385	7,787	16,318	49,946	23,250	15,264	19,462	21,574	23,483	13,203	27,347	37,193	551,912

1-6 Future OD Table of Railway (4)

Rail Passenger OD Table at Year 2000 with New Corridor Construction and with Upgrading the Section (Max. 250 km/h, Fare 100% up) (Passenger/day)

ZONE No.		1 DELHI	2 GHAZIABAD	3 BULANDSH	4 FARIDABAD	5 ALIGARH	6 MATHURA	7 AGRA	8 ETAH	9 ETAWAH	10 KANPUR	11 LUCKNOW	12 HADORI	13 BAREILLY	14 MEERUT	15 HARYANA	16 RAJASTHAN	17 MADHYA	18 BIHAR	TOTAL
1	DELHI	0	19,617	8,282	11,450	6,872	5,513	6,086	1,056	1,506	6,956	8,187	6,215	9,228	11,991	0	6,251	10,323	8,072	127,604
2	GHAZIABAD	19,617	0	1,679	1,496	927	463	643	94	153	551	1,618	1,224	2,484	2,360	0	938	1,472	1,843	37,562
3	BULANDSHAR	8,282	1,679	0	1,878	1,846	881	1,608	83	182	536	767	501	683	902	1,723	440	852	1,014	23,857
4	FARIDABAD	11,450	1,496	1,878	0	966	646	649	69	87	346	766	593	756	963	0	568	1,662	923	23,817
5	ALIGARH	6,872	927	1,846	966	0	2,950	1,830	137	252	383	1,178	803	1,108	1,249	2,529	711	1,312	1,588	26,641
6	MATHURA	5,513	463	881	646	2,950	0	1,791	168	250	462	713	450	734	613	2,374	627	2,035	1,002	21,674
7	AGRA	6,086	643	1,608	649	1,830	1,791	0	904	1,051	1,773	1,090	978	1,076	1,320	5,737	1,493	5,030	1,366	34,424
8	ETAH	1,056	94	83	69	137	168	904	0	328	524	556	428	424	305	1,084	303	591	720	7,774
9	ETAWAH	1,506	153	182	87	252	250	1,051	328	0	2,179	1,613	1,002	703	538	1,986	575	1,232	1,538	15,184
10	KANPUR	6,956	551	536	346	383	462	1,773	524	2,179	0	5,950	3,010	2,181	1,333	4,434	1,240	2,688	14,855	49,431
11	LUCKNOW	8,187	1,618	767	766	1,178	713	1,090	556	1,623	5,950	0	0	0	0	0	0	0	0	22,446
12	HADORI	6,215	1,224	501	593	803	450	978	428	1,002	3,010	0	0	0	0	0	0	0	0	15,203
13	BAREILLY	9,228	2,484	683	756	1,108	734	1,076	424	703	2,181	0	0	0	0	0	0	0	0	19,376
14	MEERUT	11,991	2,360	902	963	1,249	613	1,320	305	538	1,333	0	0	0	0	0	0	0	0	21,574
15	HARYANA	0	0	1,723	0	2,529	2,374	5,737	1,084	1,986	4,434	0	0	0	0	0	0	0	3,616	23,483
16	RAJASTHAN	6,251	938	440	568	711	627	1,493	303	575	1,240	0	0	0	0	0	0	0	0	13,145
17	MADHYA	10,323	1,472	852	1,662	1,312	2,035	5,030	591	1,232	2,688	0	0	0	0	0	0	0	0	27,199
18	BIHAR	8,072	1,843	1,014	923	1,588	1,002	1,366	720	1,538	14,885	0	0	0	0	3,616	0	0	0	36,567
	TOTAL	127,604	37,562	23,857	23,817	26,641	21,674	34,424	7,774	15,184	49,431	22,446	15,203	19,376	21,574	23,483	13,145	27,199	36,567	546,962

1-7 OD Table of Railway

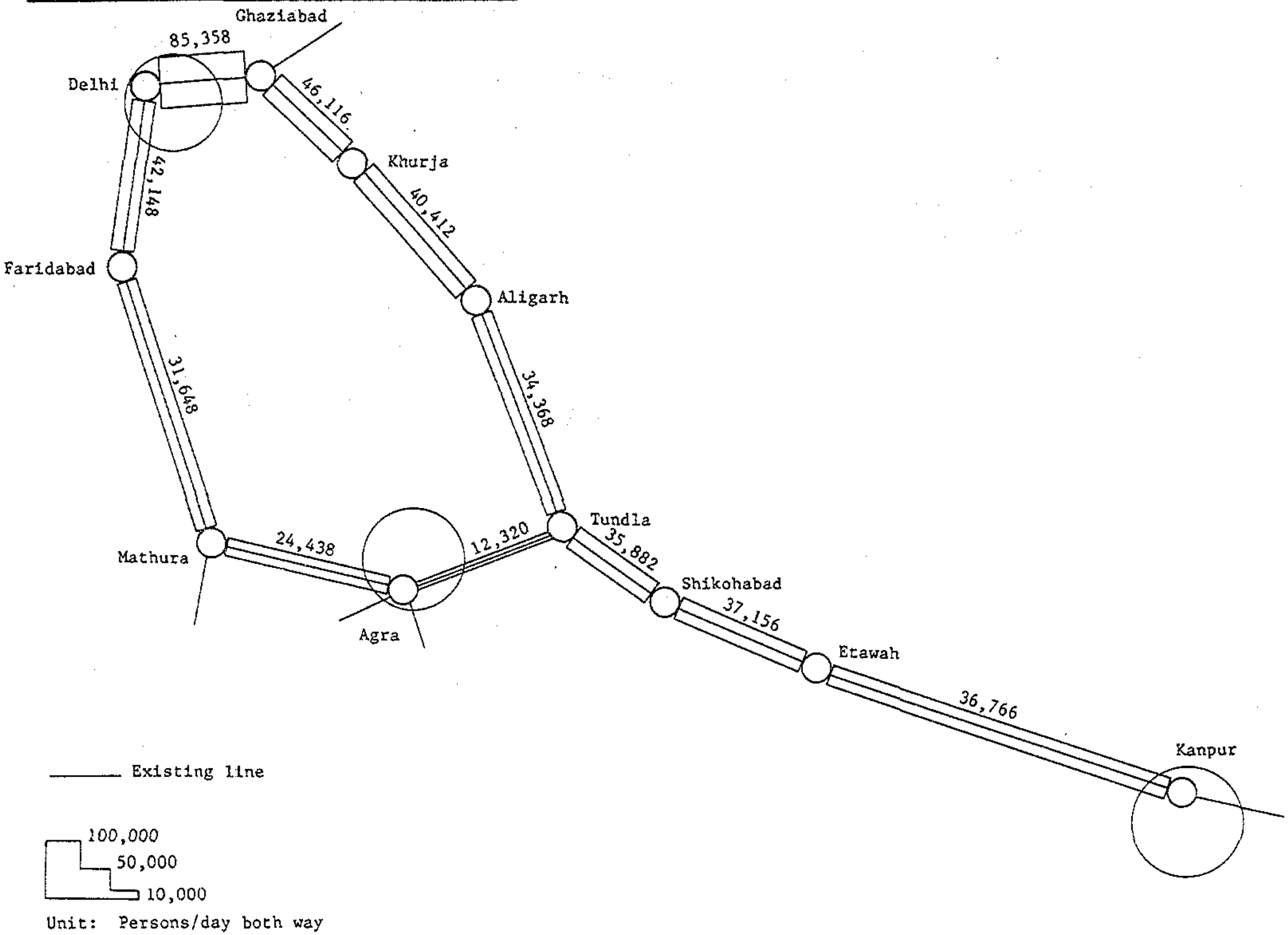
Rail Freight OD Table at Year 1985 (ton/day)

ZONE	1 DELHI	2 ALIGARH	3 MATHURA	4 AGRA	5 ETAH	6 KANPUR	7 LUCKNOW	8 SHAJAHANPUR	9 MORADABAD	10 MEERUT	11 HARAYANA	12 RAJASTHAN	13 MADHYA PRADE	14 BIHAR	TOTAL
1 DELHI	9	82	2	16	2	77	75	21	14	90	443	187	1,433	698	3,148
2 ALIGARH	30	14	1	11	3	105	23	0	4	10	83	136	486	567	1,473
3 MATHURA	1,143	74	0	68	3	323	237	18	468	569	4,164	653	1,672	1,072	10,463
4 AGRA	6	1	2	0	5	12	26	2	10	74	317	30	223	160	868
5 ETAH	11	1	0	17	0	44	14	1	88	12	23	68	392	417	1,089
6 KANPUR	347	151	4	50	50	19	403	72	524	386	545	21	277	1,125	3,974
7 LUCKNOW	98	30	5	20	3	61	0	0	0	0	0	0	0	0	218
8 SHAJAHANPU	9	5	5	20	13	226	0	0	0	0	0	0	0	0	279
9 MORADABAD	34	5	3	17	15	185	0	0	0	0	0	0	0	0	259
10 MEERUT	321	75	15	78	102	118	0	0	0	0	0	0	0	0	709
11 HARYANA	6,257	761	66	577	80	379	0	0	0	0	0	3,282	12,544	14,763	38,708
12 RAJASTHAN	2,526	248	65	557	35	793	0	0	0	0	11,157	0	0	0	15,381
13 MADHYA	5,723	1,311	151	1,018	129	1,761	0	0	0	0	16,272	0	0	0	26,364
14 BIHAR	14,287	7,646	128	1,621	277	4,900	0	0	0	0	26,197	0	0	0	55,056
TOTAL	30,801	10,402	448	4,070	718	9,002	778	113	1,107	1,142	59,200	4,378	17,027	18,802	157,988

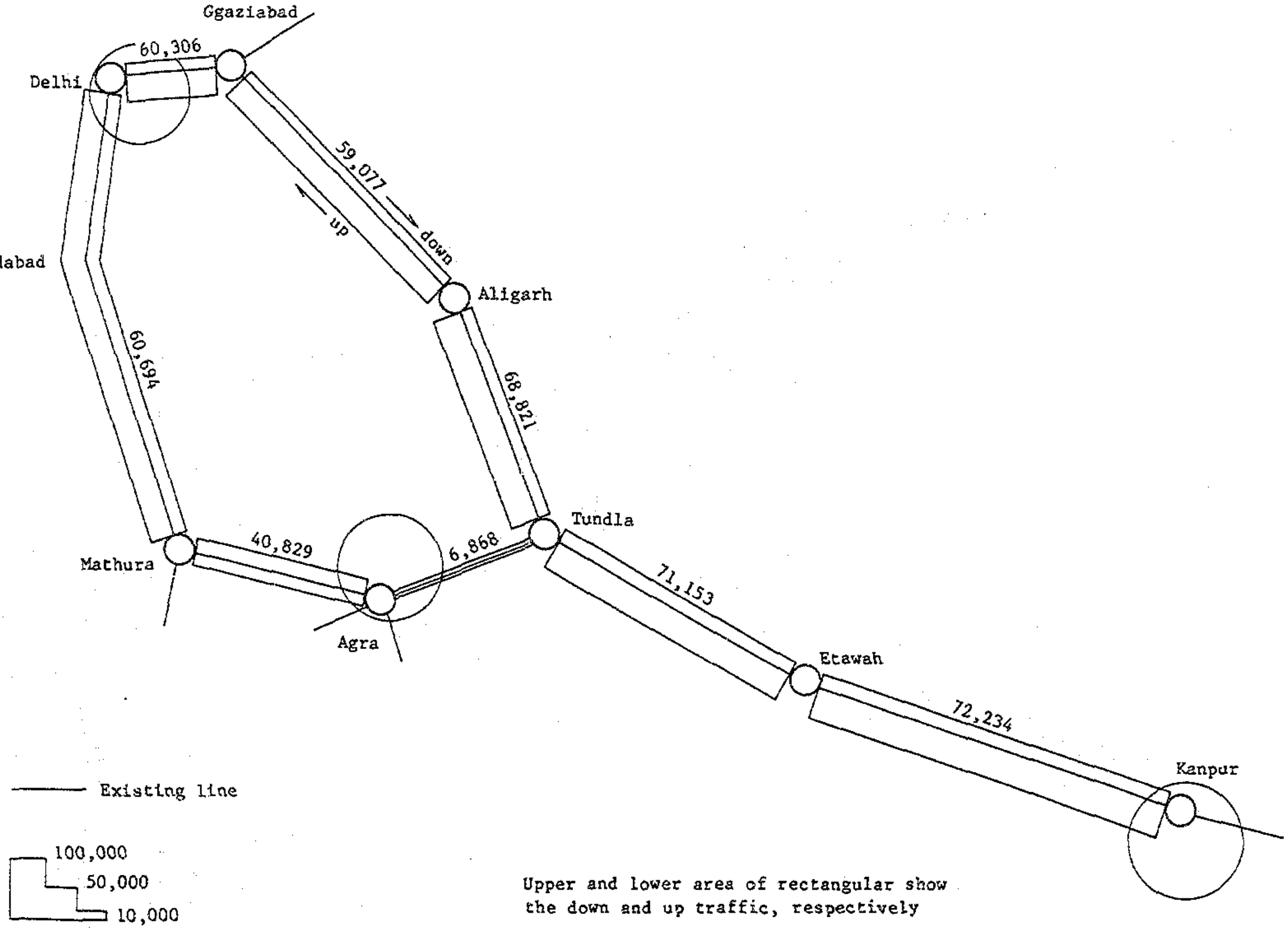
Rail Freight OD Table at Year 2000 (ton/day)

ZONE	1 DELHI	2 ALIGARH	3 MATHURA	4 AGRA	5 ETAH	6 KANPUR	7 LUCKNOW	8 SHAJAHANPUR	9 MORADABAD	10 MEERUT	11 HARAYANA	12 RAJASTHAN	13 MADHYA	14 BIHAR	TOTAL
1 DELHI	30	256	7	65	6	249	201	56	36	242	1,331	531	4,042	1,924	8,955
2 ALIGARH	95	40	2	30	8	309	56	1	10	25	228	354	1,254	1,429	3,838
3 MATHURA	3,231	196	0	163	8	881	534	40	1,007	1,294	10,547	1,561	3,974	2,490	25,928
4 AGRA	18	1	6	0	11	33	59	5	21	169	804	72	530	373	2,102
5 ETAH	33	3	0	43	0	123	31	1	194	28	61	167	952	990	2,625
6 KANPUR	1,111	451	10	138	139	57	1,030	185	1,278	995	1,564	57	744	2,960	10,719
7 LUCKNOW	257	73	12	44	7	155	0	0	0	0	0	0	0	0	548
8 SHAJAHANPU	24	11	12	46	30	572	0	0	0	0	0	0	0	0	694
9 MORADABAD	94	14	7	40	36	499	0	0	0	0	0	0	0	0	691
10 MEERUT	848	185	34	175	234	301	0	0	0	0	0	0	0	0	1,776
11 HARYANA	18,492	2,103	164	1,456	204	1,081	0	0	0	0	0	8,194	31,148	35,830	98,674
12 RAJASTHAN	7,271	669	158	1,369	87	2,200	0	0	0	0	28,762	0	0	0	40,517
13 MADHYA	16,038	3,437	357	2,434	313	4,758	0	0	0	0	40,834	0	0	0	68,172
14 BIHAR	38,636	19,347	292	3,742	648	12,779	0	0	0	0	63,441	0	0	0	138,885
TOTAL	86,177	26,789	1,060	9,724	1,731	23,998	1,912	287	2,544	2,754	147,572	10,935	42,644	45,995	404,123

1-8 Assumed Passenger Link Traffic in 1985



1-9 Freight Link Traffic in 1985



Unit: Freight ton/day, Figure: both way

Upper and lower area of rectangular show the down and up traffic, respectively

1-10 Current Transport Volume at Each Station (Delhi-Kanpur)

Station	Passenger transport		Freight transport							
	No. of boarding passengers		Tonnage coming-in		Tonnage going-out		No. of wagons coming-in		No. of wagons going-out	
Fiscal year	1984	1985	1984	1985	1984	1985	1984	1985	1984	1985
Delhi	36,421	33,822			16				0.2	
New Delhi	41,234	40,484	6,400	6,567	1,073	975	260	260	72	68
Delhi Shahadara	14,484	14,023	28	33	6	12	2	2	0.7	0.9
Sahibabad	3,721	4,017	242	171	158	187	12	10	2	2
Ghaziabad	18,282	19,190	2,203	2,810	2,097	3,163	101	103	9	10
Chipayana Bzurg Maripat	774	801								
Dadri	4,040	3,613	32	31	4	1	2	2	0.2	0.1
Boraki Halt	194	185								
Ajaibpur	649	623								
Dankaur	4,123	4,338	9	10	108	127	0.8	0.6	5	7
Wair	494	390								
Chola	650	548								
Sikandarpur	184	218								
Khurja	2,276	2,075	3	2	86	139	0.1	0.2	4	6
Kamalpur Halt	125	128								
Danwar	297	423								
Somna	889	638								
Kulwa	279	215								
Mehrawal	55	42								
Aligarh	11,487	12,751	666	430	174	197	23	24	8	9
Daud Khan	158	178								
Mandrak	661	761								
Sashi	569	638	1	1	3	3	0.1	0.1	0.4	0.3
Hathras	1,624	1,727	142	55	93	106	6	5	4	5
Pora	690	347								
Jalesar	851	937								
Chamorola	267	262								
Barhan	629	603								
Mitawali	175	162								
Tundla	2,948	3,547	13	18	16	14	0.6	2	1	1
Hirangaon	365	319								
Firozabad	1,687	2,046			7	12			1	1
Makkhanpur	351	280	11	11	156	35	5	0.5	7	2
Shikohabad	1,883	2,111								
Kaurara	215	227								
Bhadan	367	427								
Barlai	266	267								
Jaswant	361	409	7	4	28	27	0.4	0.2	1	1
Sarai Bhupat	54	60								
Etawah	3,732	4,236	76	86	198	129	6	5	7	6
Ekdil	208	230								
Bharthana	1,552	1,648	10	5	88	37	0.5	0.3	2	1
Samhon	243	285								
Achalda	1,353	1,354	2	1	5	6	0.1	0.1	0.3	0.2
Pata	262	298								
Phaphund	2,233	2,217	7	6	59	74	0.4	0.5	3	4
Kanchausi	449	432								
Jhinjhak	1,593	1,670								
Ambiapur	454	458								
Rura	1,440	1,394	4	5	2	2	0.2	0.2	0.1	0.1
Roshan Mau Halt	100	131								
Maitha	541	560								
Bhaupur	652	529								
Panki	361	366	4,163	2,918	2,019	2,160	145	131	95	98
Govindpuri	1,119	1,243								
Juhi Yard Kanpur Central		*1 2,781			*2 27	*2 17			2	1
Total	171,071	173,664	14,019	13,164	6,423	7,423	565.2	546.7	224.9	223.6

*1 : Upper class passegers between Delhi and Kanpur
*2 : Freight traffic volume between Delhi and Kanpur

1-10 Current Transport Volume at Each Station (Faridabad - Agra Cant)

Station / Fiscal year	Passenger transport No. of boarding passenger 1986
Faridabad	2,848
Fardabad N.T.	2,434
Ballab Garh	1,861
Bad	44
Mathura	3,123
Bhteshwar	682
Vrindaban Road	213
Ajhai	1,361
Chatta	231
Kosi	952
Hodal	281
Sholak	172
Rundi	322
Palwal	2,059
Asaoti	592
Frah	62
Kitam	63
Runkta	55
Blochpura	62
Agra City	708
Rajaki Mandi	1,985
Agra Cant	6,744
Total	26,853

2-1 Train Diagram Pattern (New Corridor)

Train Number Ratio between DLI-AGC and AGC-CNB Sections

	DLI ∿ AGC	AGC ∿ CNB
S. Express 250 km/h	2 :	2 :
L. Express 160 km/h	2	1

$$N = \frac{H \times 60 \times f}{h} \times A$$

$$= \frac{(24-4) \times 60 \times 0.8}{50} \times 4$$

$$\doteqdot 77 \rightarrow 80$$

N = Track capacity
H = Time zone for train operation (excluding 4 hours for maintenance work)
f = Track use ratio ... 0.8
h = Period required per pattern (min)
A = Train number per pattern

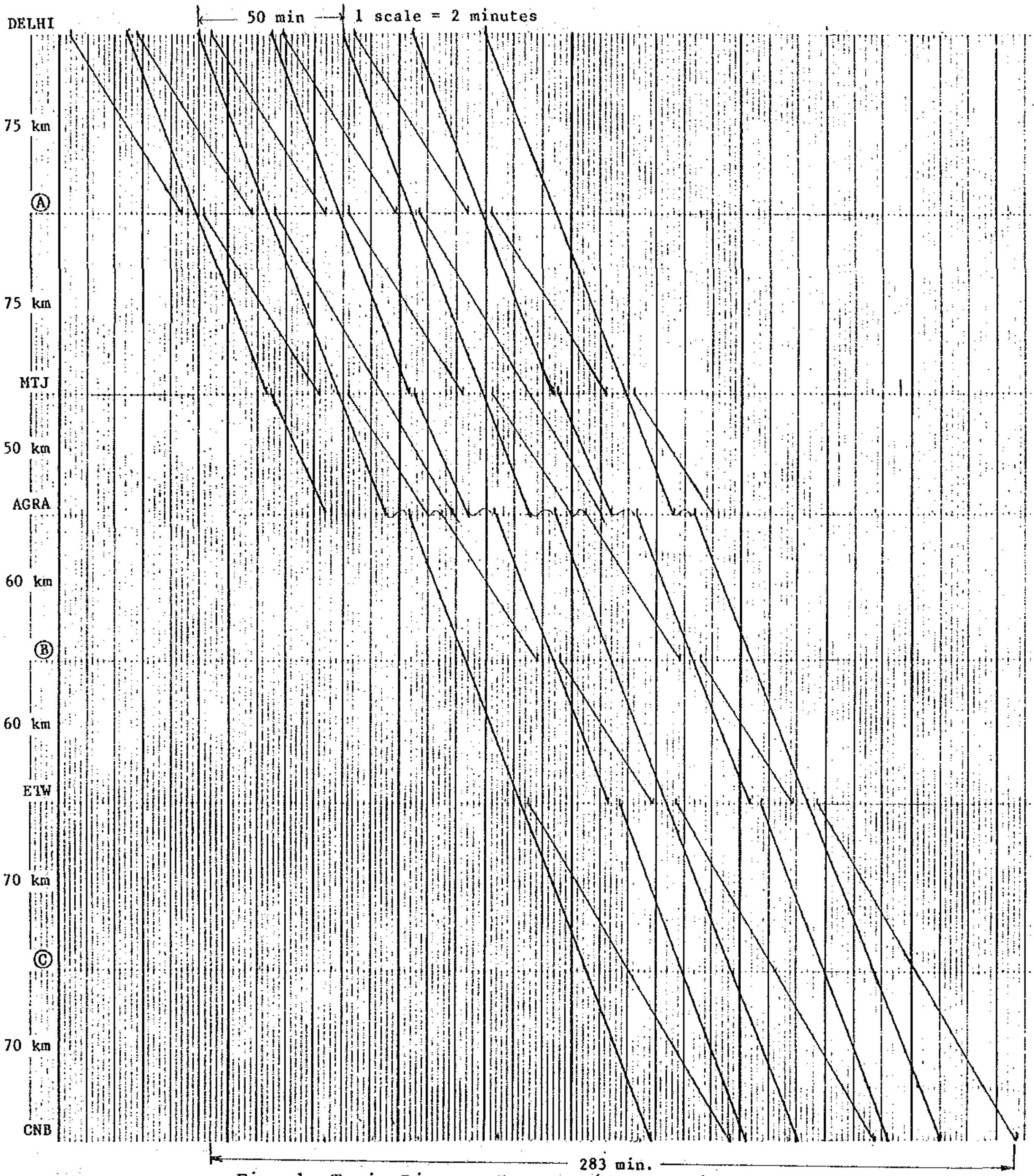


Fig. 1 Train Diagram Pattern (New Corridor)

Train Number Ratio between DLI-AGC and AGC-CNB Sections

	DLI – AGC	AGC – CNB
S. Express 200 km/h	2	2
	:	:
L. Express 160 km/h	2	1

N = Track capacity
H = Time zone for train operation (excluding 4 hours for maintenance work)
f = Track use ratio ... 0.8
h = Period required per pattern (min)
A = Train number per pattern

$$N = \frac{H \times 60 \times f}{h} \times A$$

$$= \frac{(24-4) \times 60 \times 0.8}{38} \times 4$$

$$\doteqdot 101 \rightarrow 100$$

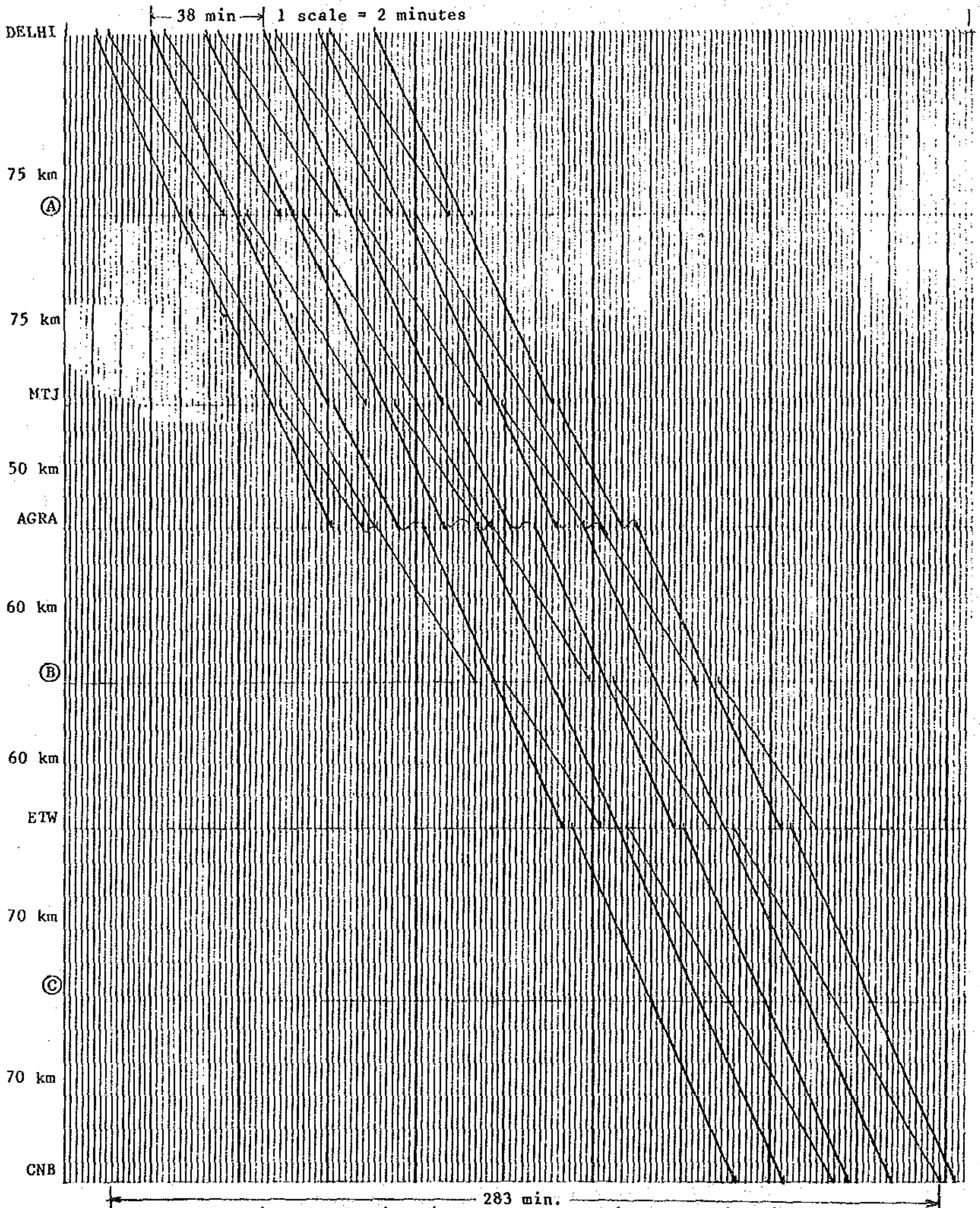


Fig. 2 Train Diagram Pattern (New Corridor)

2-2 Margin Time

In operating trains, it is most desirable to run them in accordance with a fixed schedule. It is unavoidable, however, that their operation is sometimes delayed due to construction work, accidents, and bad weather. For this reasons, a certain margin time is provided in the time schedule.

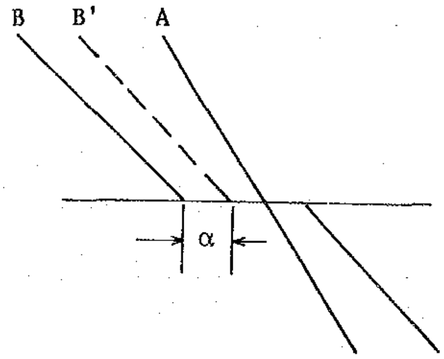
How much percentage of the standard operation time should be set aside for margin time varies with the types of trains.

For instance, a delay in the operation of Train A which will be connected to many trains may affect a wide area of railway sections for a long period of time, while the same delay of Train B may hardly influence operations of other sections and time periods.

Accordingly, extensive study is needed on how much time should be secured for margin time. It is customary for JR, however, to set aside around 2% of the standard operation time of super express trains and 3 ∿ 4 % of that of express trains for margin time based on past experience.

In actual train diagrams, however, some time is additionally allotted to the above time in connection with various factors such as overtaking trains, yard-work, stoppage at major stations and other technological considerations related to diagrams.

As for other trains (local passenger trains and freight trains), there are many cases in which the loss time like α in Fig. 1 has the same meaning as the margin time and if examined in completed train diagrams, the loss time will amount to about 8 ∿ 10%. From above reason, formal margin time for these trains is not allotted except in special cases.



A: High-speed train
B: Low-speed train
B': Low speed train (with minimum stopping time for being taken over by a high-speed train)
α: Loss time of Train B

Fig. 1 Loss Time in Overtaking-stop

2-3 Assumed Traffic Volume at the Time of Completion of the 7th Five Year Plan (1990)

The 7th Five-Year Plan of the IR calls mainly for reinforcement of transport capacity during 1985 ∿ 1990. Its objectives are being attained in stages.

With regard to the section between Delhi and Kanpur, construction of block huts, storage loops, and extension of platforms are provided for in the plan.

The Traffic volume in the section between Delhi and Kanpur at the time of the completion of the 7th Five Year Plan, estimated in consideration of the past record and existing situation, is as follows. The estimate is based on the assumption that, since transport demand will continue surpassing transport capacity until 1990, the transport capacity and actual traffic volume will be equal.

1) Increase in train kilometers

The per-day train kilometers between GZB and CNB in the period from 1980/81 to 1986/87, calculated on the basis of the operated train number are as follows:

Table 1 Increase in Train Kilometers

(Train-km/day)

	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87
Passenger	17,390	17,560	17,840	18,670	20,530	20,530	20,860
Freight	17,380	17,326	18,560	18,670	17,880	23,220	24,000
Total	34,770	34,886	36,400	37,340	38,410	43,750	44,860

The annual growth rate of total train kilometers has been 4.3% on an average between 1980/81 ∿ 1986/87 and 2.5% between 1985/86 and 1986/87.

Since reinforcement of such facilities as block huts and storage loops is being pushed in the Section, and some transport capacity build-up can be expected, the growth rate of 2.5% is adopted.

Accordingly, the anticipated increase in the total train kilometers between 1985 and 1990 are calculated as follows:

43,750 (km) x $1,025^5$ = 49,500 (train-km/day)
49,500 (km) - 43,750 (km) = 5,750 (train-km/day)

The km increment is to be allotted evenly (50% each) to passengers and freight.

2) Per-train Increase in Transport Capacity

a) Passenger Train

The rate of annual increase in the number of connected coaches per train in the Allahabad Division between 1981/82 and 1985/86 was 3.7% on an average, according to DOMESTIC STATISTICS PART-1, Traffic (1986 - NORTHERN RAILWAY).

Load in bogies (Normal) for Exp./Mail in the Section in 1985/86 was 17.6 coaches. Assuming that the similar growth to that of the Allahabad Division is attained in that Section, the formation length in 1990 will be around 21 coaches on average.

In view of the effective length of tracks and platforms, it is considered difficult to comprise all trains with 21 coaches. If the number of coaches is increased to the level of Load in Bogies (maximum), namely 18∿21 in accordance with OPERATING DEPARTMENT BROAD GAUGE (1986 NORTHERN RAILWAY), the increment will be about 2,080 passengers/day (equivalent to 2 additional trains of 18-coach formation).

If local trains are increased in stages to the level of Load in Bogies (Maximum) - 14 ∿ 17 coaches, the local train increment will become about 1,620 ∿ 3,400 persons/day.

b) Freight Train

The annual rate of per-train increase in transport volume in the Allahabad Division between 1981/82 and 1985/86 was 4.6% on an average, according to DOMESTIC STATISTICS PARTS-1, Traffic (1986 NORTHERN RAILWAY).

On the assumption that an average annual growth of 4.6% can be secured from 1985 to 1990 by increasing Box-N wagons and 9,000-ton trains, the following per train transport volume can be anticipated between Ghaziabad and Kanpur.

Table 2 Transport Volume Per-Train

(ton/train)

	GZB ALJN TDL ETW CNB			
*1985	1,425	1,434	1,594	1,616
1990	1,780	1,790	1,990	2,020

* Based on the Freight Link Traffic of 4-2-1, (2)-3) of this Report.

3) Estimated Traffic Volume in 1990

Based on results of prediction under 1) and 2), the traffic volume in 1990 is presumed to be as follows:

a) Passenger

Table 3 Passenger Traffic Increase by 1990

(man/day)

	GZB KRJ ALJR TDL SKB ETW CNB					
1985	44,892	41,478	41,286	44,924	40,674	42,274
Increase of train kilometers*	6,900	6,900	6,900	6,900	6,900	6,900
Increase of connected coaches	3,700	3,700	4,744	5,484	3,856	4,744
1990	55,492	52,078	52,930	57,308	51,430	53,918

*1 The additional number of passengers as a result of the increase in train kilometers is as follows:

- $5,750^{(km)} \div 2 = 2,875^{(km)}$ .... Increase in train kilometers
- $2,875^{(km)} \div 438.2^{(km)} = 6^{(trains)}$ ... Increase in the number of trains
- $1,040^{(persons)} \times 3^{(trains)} = 3,120^{(persons)}$ ... 18-car formation

  $1,260^{(persons)} \times 3^{(trains)} = 3,780^{(persons)}$ ... 21-car formation

  Total: $6,900^{(persons)}$

*2 The additional number of passengers as a result of the increase in the number of connected coaches is as follows:

. Exp./Mail: 36 coaches for 14 trains (equivalent to two trains of 18 coach formation) $1040^{(persons)} \times 2 = 2{,}080^{(persons)}$

. Local 1,620(person) ∿ $3{,}404^{(persons)}$

b) Freight

Table 4 Traffic Volume Increase by 1990

(ton/day)

	GZD	ALJN	TDL	ETW	CNB
1985	59,077	68,821	71,153	72,234	
Increase in train kilometers *1	10,680	10,740	11,940	12,120	
Increase in hauling tonnage *2	14,770	17,150	17,750	18,060	
1990	84,527	96,711	100,843	102,412	

*1 The increase in transported tonnage due to the increase in train kilometers is as follows:

. $5{,}750^{(km)} \div 2 = 2{,}875^{(km)}$ .... Increase in freight train kilometers

. $2{,}875(km) \div 411.7^{(km)} = 6^{(trains)}$ ... Increase in the number of trains

. 6(trains) x hauling tonnage per train for respective sections (1990)

*2 The transported tonnage due to the increase in hauling tonnage is calculated as follows:

. The numbers of trains for respective sections multiplied by the increase in the per-train hauling tonnage.

The train numbers for respective sections in 1985 are as follows:

GZB - ALJN ... 41.5 (trains)

ALJN - TDL ... 47.9 (trains)

TDL - ETW .... 44.6 (trains)

ETW - CNB .... 44.7 (trains)

2-4 Use of EMU for Local Passenger Trains

The distance between stations for local trains is relatively short, with many of them being less than 10 km. The average distance between stations is 6 km for the GZB ∿ TDL section (about 184 km) and 7 km for the TDL ∿ CNB section (about 228 km).

For the GZB ∿ C.BUZUG section (3.6 km) and the CHL ∿ SKQ section (9.2 km) in the GZB ∿ ALJN section (about 131 km), comparison of the standard operation time is made between the case of EL (WAG-4) traction train of 1,000 tons and EMU (1M3T x 2) train.

Notes: 1. Regarding EMU, running performance at more than 75 km/h is estimated.

2. It is assumed that the track is straight, the gradient is level, and there is no limit on train operation speed.

As shown in Fig. 1, EMU trains feature high acceleration and deceleration. For local passenger trains which are operated in small inter-station distance, therefore, use of EMU is effective in shortening operation time and recovery of delay. In addition since EMUs require no connection changes and allow shorter yard-work and shuttling time, their employment in suburban transport, which requires high transport capabilities and faces the problem of insufficient platform capacity, is desired.

Table 1 Example of Operation Time Reduction Effect

	GZB ∿ C.BUZUG	CHL ∿ SKQ
WAM-4 (1,000 ton)	4'46"	8'54"
EMU	4'00"	8'00"
Shortened operation time	46"	54"

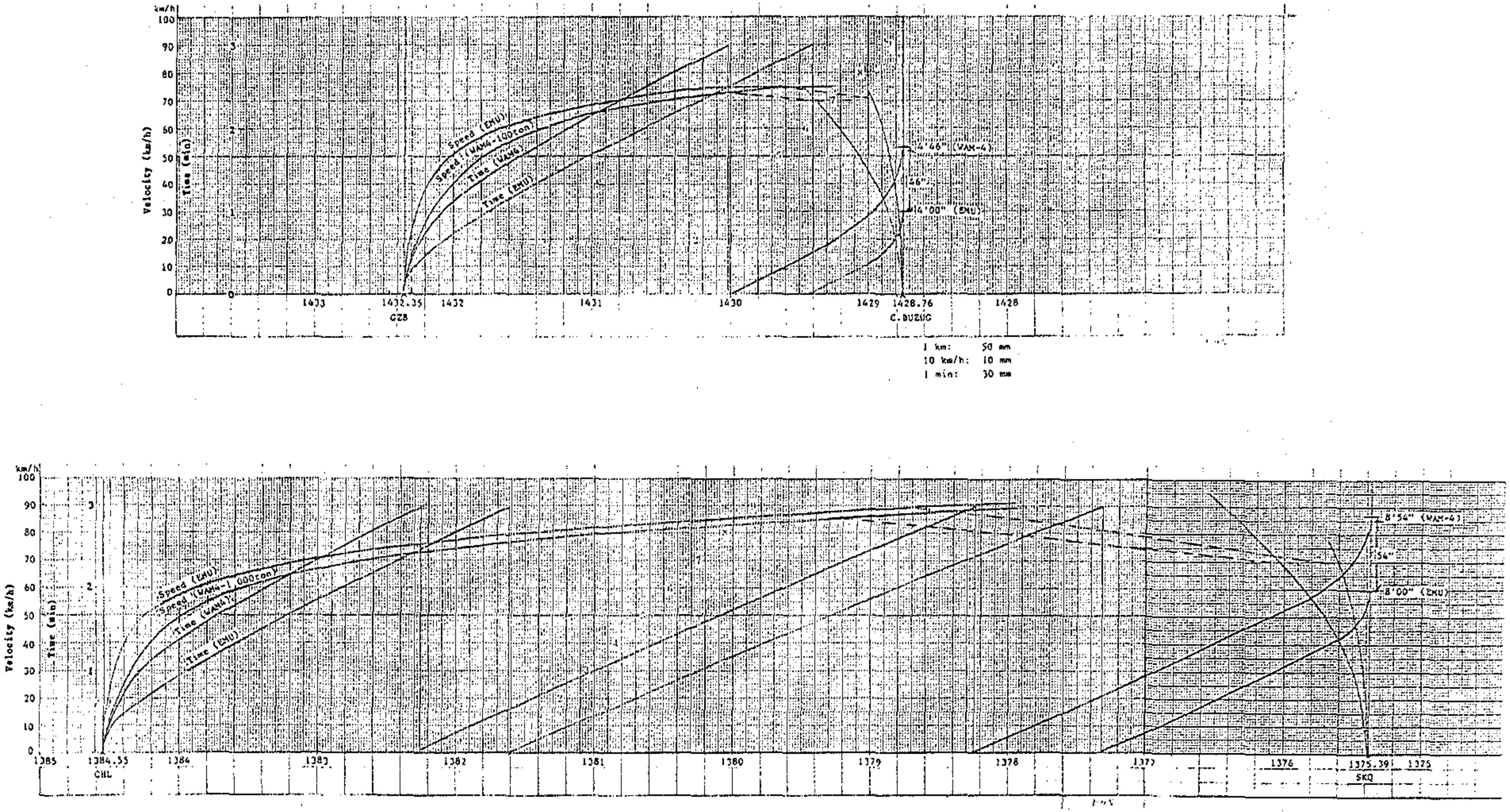


Fig. 1 Train Operation Diagram (Locomotive and EMU)

2-5 Track Capacity

As a result of calculation based on the automated signals and improved train speed, and also applying the ratios of number of trains by types, as indicated below, the track capacity turns out as shown below.

1) Ratio of train types

The ratios of number of trains by types are assumed as follows.

. L. Exp. 1
. Exp. Mail 14
. Local 2
. Fast (freight) 7
. Ordinary (freight) 10
. Total 34

2) Pattern diagram and time required for one cycle

With average distance of approx. 10 km between two locations of passing tracks (including passing tracks to be prepared newly between GZB and CNB), and the aforementioned train number ratio by types, the pattern diagram can be composed with approximately 270 minutes per cycle.

3) Rough calculation of track capacity

The track capacity is roughly calculated as follows.

. Preconditons:

. H = Train operation time zone ...
22 hours (2 hours are for maintenance)

. α = Margin time ratio
20% of running time

. f = Track usable rate
75% (upper limit of actual data of JR)

. P = Time required for 1 cycle of trains pattern
270 min

. A = No. of trains in 1 cycle of train pattern
34 trains

. N = Track capacity (number of trains)

$$N = \frac{H \times 60 \times f \times A}{P\ (1 + \alpha)} = 103 \text{ (trains)}$$

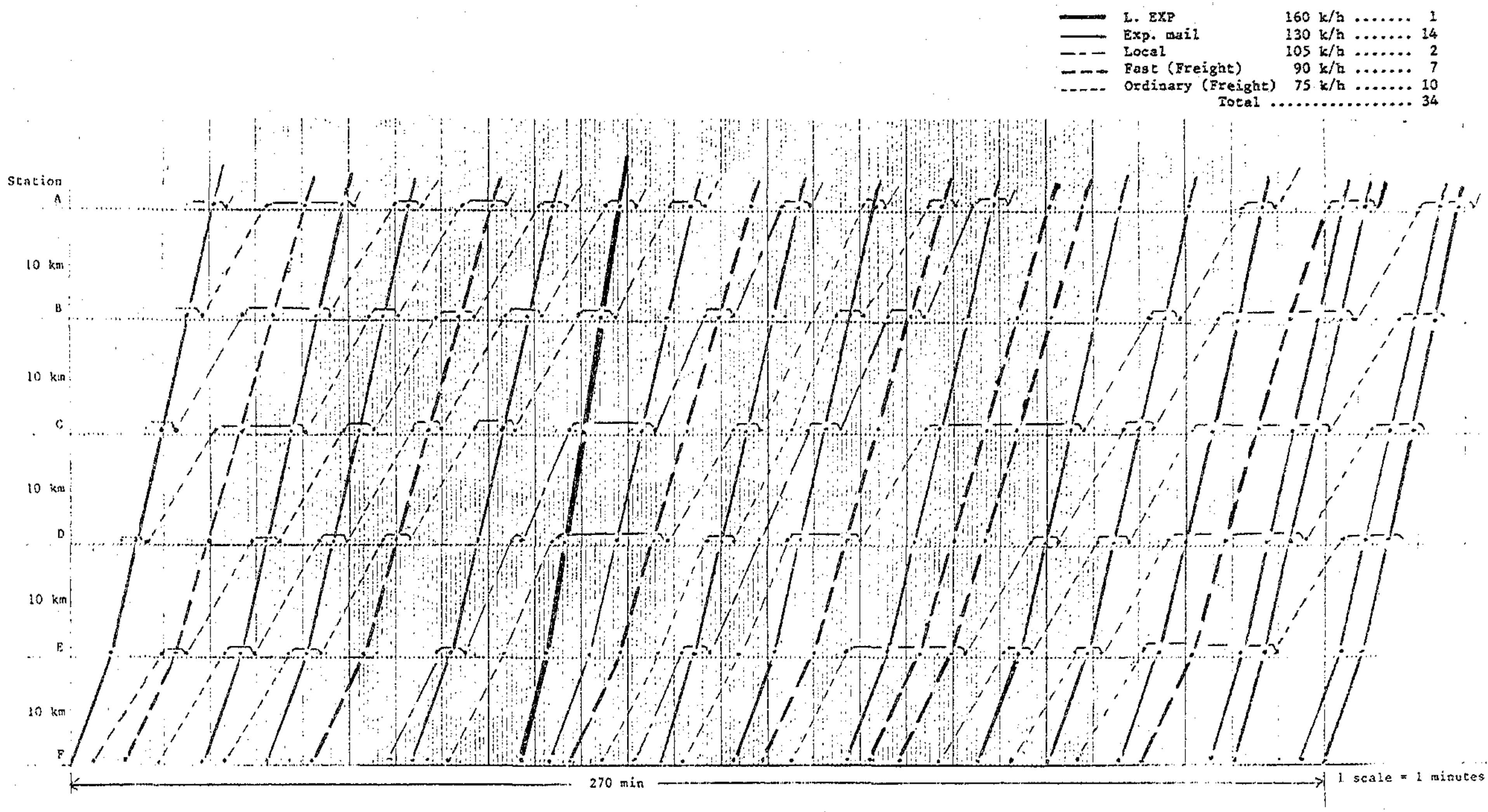


Fig. 1 Model Diagram Pattern (The Section)

2-6 Number of Trains by Year Without Construction of the New Corridor

Table 1 The Section

	Year	Train		DLI–GZB	GZB–KRJ	KRJ–ALJN	ALJN–TDL	TDL–SKB	SKB–BTW	BTW–CNB
Actual Record	1985	Pass.	L. Exp	-	-	-	-	-	-	-
			Exp. Mail	(40)	40	40	40	44	42	42
			Local	(10)	10	12	10	8	4	6
			V.P	(2)	2	2	2	2	2	2
			Total	(52)	52	54	52	54	48	50
		Fre.	Fast		-	-	-	-	-	-
			Ord.		39	45	48	44	46	44
			Total		39	45	48	44	46	46
		M			1	1	1	2	2	2
		Total			92	100	101	100	96	98
After implementation of the 7th five year plan	1990	Pass.	L. Exp	-	-	-	-	-	-	-
			Exp. Mail	(43)	43	43	43	47	45	45
			Local	(10)	10	12	10	8	4	6
			V.P	(2)	2	2	2	2	2	2
			Total	(55)	55	57	55	57	51	53
		Fre.	Fast		-	-	-	-	-	-
			Ord.		43	49	54	49	51	51
			Total		43	49	54	49	51	51
		M			1	1	1	2	2	2
		Total			99	107	110	108	104	106
After upgrading the section	1991	Pass.	L. Exp	(4)	4	4	4	4	4	4
			Exp. Mail	(52)	52	52	52	47	45	45
			Local	(10)	10	12	10	8	4	6
			V.P	(2)	2	2	2	2	2	2
			Total	(68)	68	70	68	61	55	57
		Fre.	Fast		20	20	20	20	20	20
			Ord.		23	29	36	30	32	32
			Total		43	49	56	50	52	52
		M			1	1	1	2	2	2
		Total			112	120	125	113	109	111
	1995	Pass.	L. Exp	(5)	5	5	5	5	5	5
			Exp. Mail	(67)	67	67	67	58	56	56
			Local	(11)	11	12	10	8	4	6
			V.P	(4)	4	4	4	4	4	4
			Total	(87)	87	88	86	75	69	71
		Fre.	Fast		30	30	30	30	30	30
			Ord.		25	31	41	34	36	36
			Total		55	61	71	64	66	66
		M			1	1	1	2	2	2
		Total			143	150	158	141	137	139
	2000 ~ 2015	Pass.	L. Exp	(7)	7	7	7	7	7	7
			Exp. Mail	(93)	93	93	86	78	76	76
			Local	(12)	12	12	10	8	4	6
			V.P	(4)	4	4	4	4	4	4
			Total	(116)	116	116	107	97	91	93
		Fre.	Fast		37	37	37	37	37	37
			Ord.		41	47	60	51	53	53
			Total		78	84	97	88	90	90
		M			2	2	2	4	4	4
		Total			196	202	206	189	185	187

Note: 1. The Number Train is total of up and down trains per day. Train respectively.
2. Pass, Fre., V.P, Ord and M in the "Train" Column are Passenger, Freight, Parcel, Ordinary and Miscellaneous Train, respectively.

2-7 Operation Time Reduction Effect due to Higher Point Limit Speed

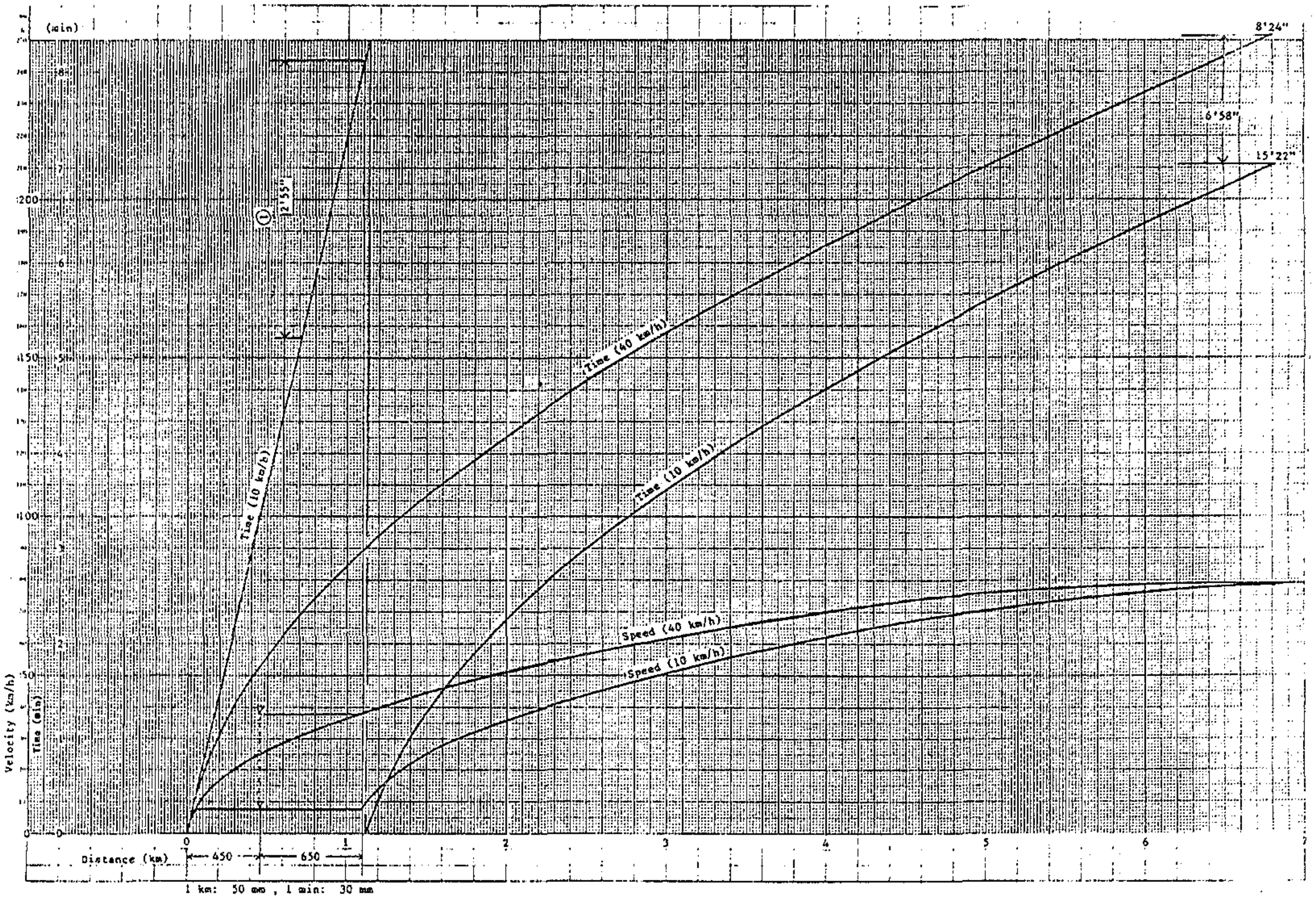


Fig. 1 Departure (Freight Train of 4,500 tons and WAG6 Traction)

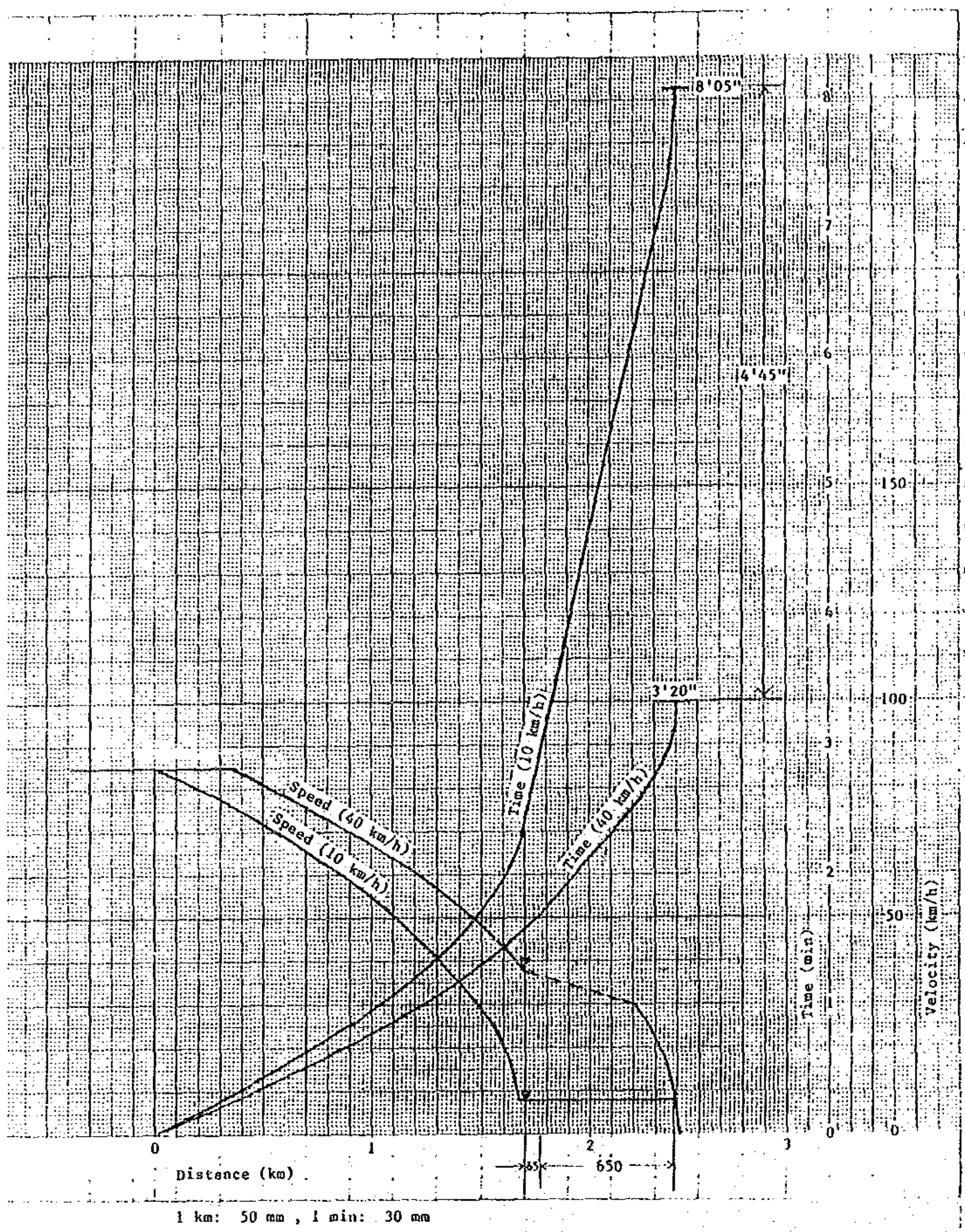


Fig. 2 <u>Arrival (Freight Train of 4,500 tons and WAG 6 Traction)</u>

2-8 Number of Trains by Year and Fare Increase Rate (The Section)

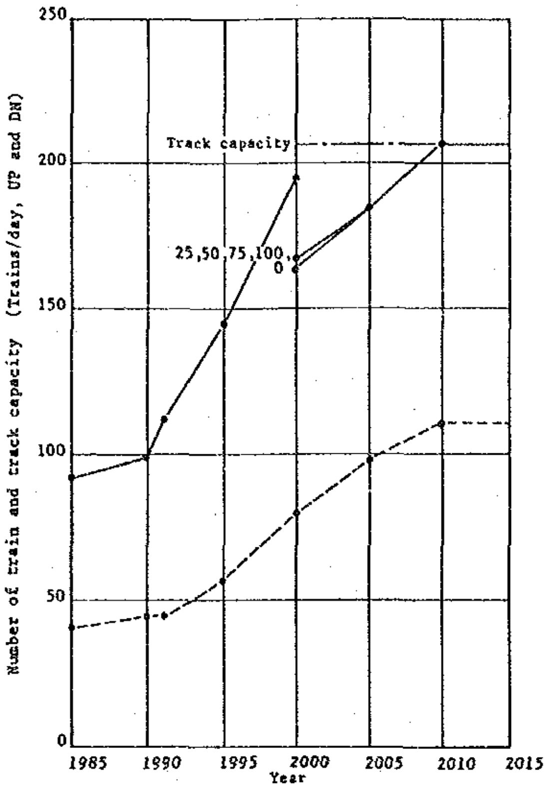


Fig. 1 GZB - KRJ

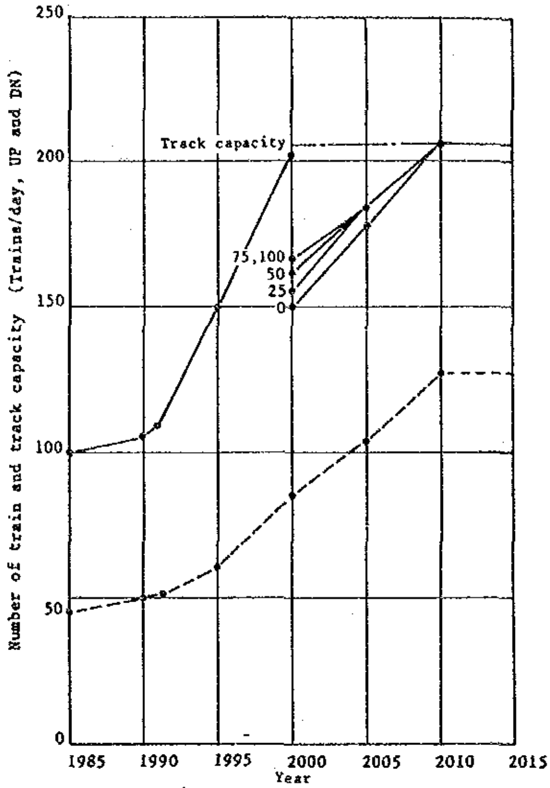


Fig. 2 KRJ - ALJN

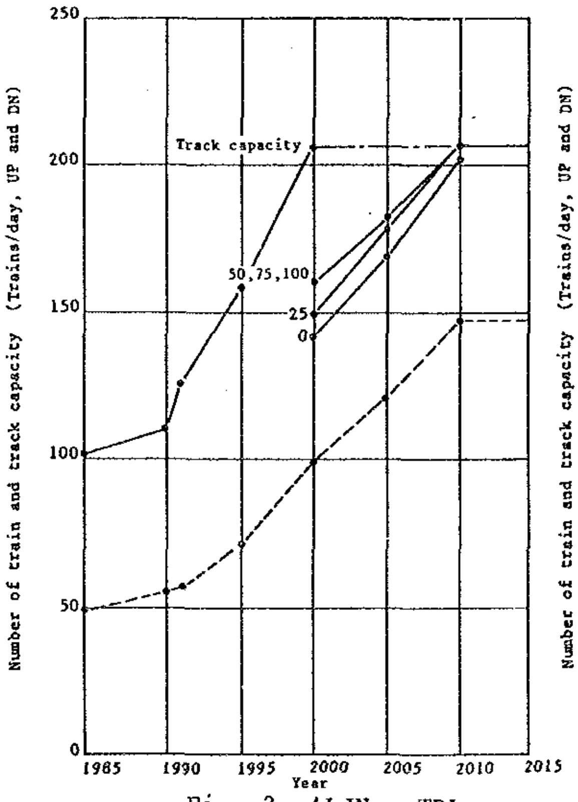


Fig. 3 ALJN - TDL

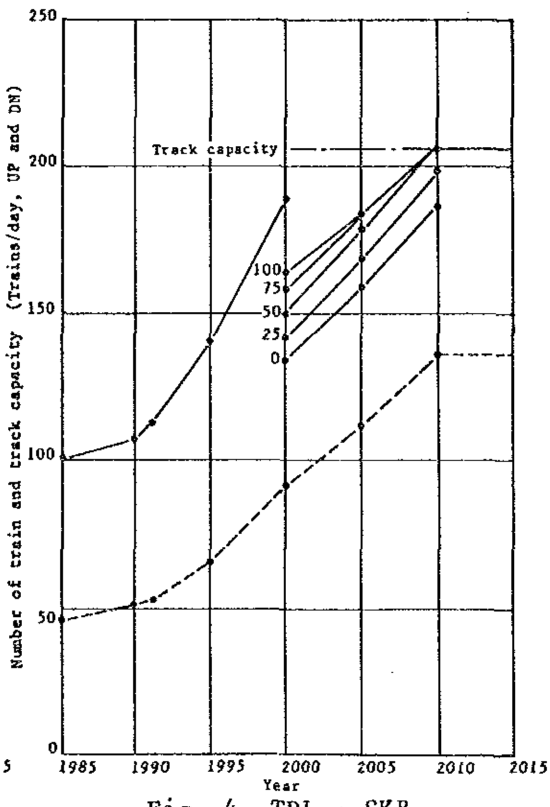


Fig. 4 TDL - SKB

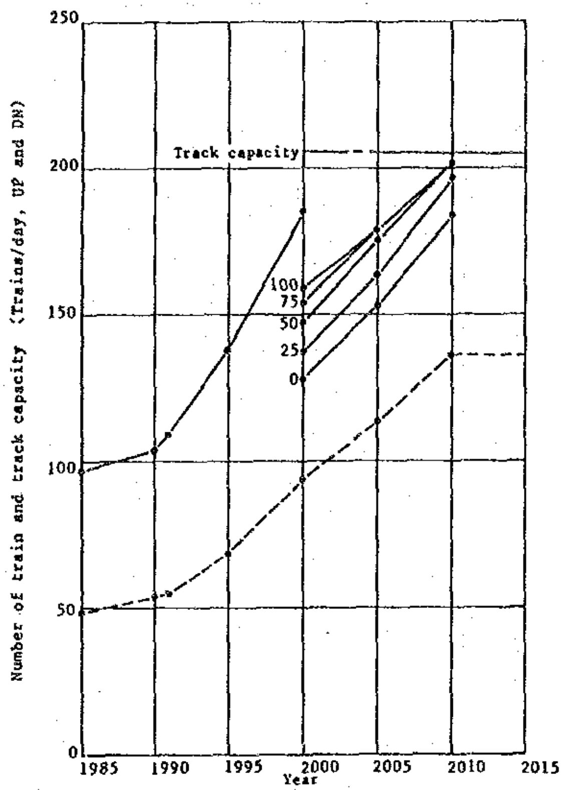


Fig. 5 SKB - ETW

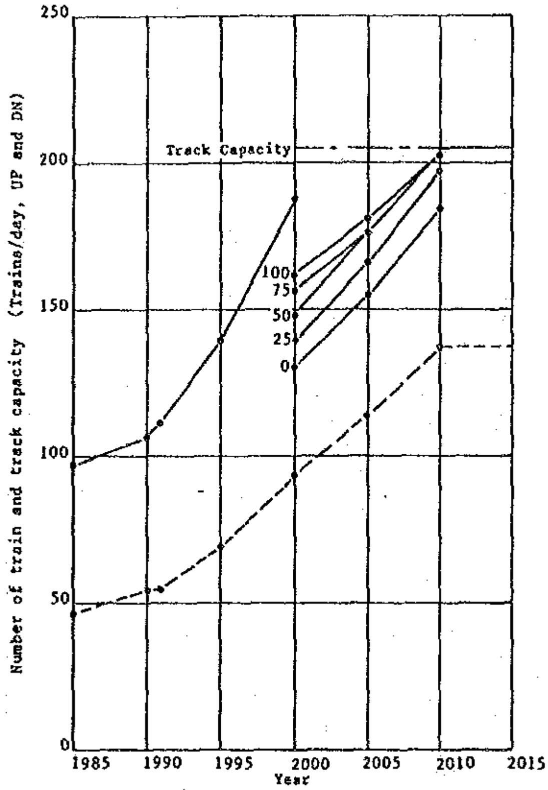


Fig. 6 ETW - CNB

Note 1. ——— No. of Train (Total)
- - - - No. of Train (Freight)
——— - ——— Track Capacity

2-9 Train Number of the Section by Year and the Fare of the New Corridor

Table 1 Number of Train by Year after Construction of the New Corridor

0% UP

(the Section)

Year	Train		DLI – GZB	GZB – KRJ	KRJ – ALJN	ALJN – TDL	TDL – SKB	SKB – ETW	ETW – CNB
2000	Pass.	Exp. Mail	(68)	68	48	28	28	26	26
		Local	(12)	12	12	10	8	4	6
		V.P	(4)	4	4	4	4	4	4
		Total	(84)	84	64	42	40	34	36
	Fre.	Fast		37	37	37	37	37	37
		Ord.		41	47	60	51	53	53
		Total		78	84	97	88	90	90
	M			2	2	2	4	4	4
	Total			164	150	141	132	128	130
2005	Pass.	Exp. Mail	(70)	70	57	34	33	31	31
		Local	(12)	12	12	10	8	4	6
		V.P	(4)	4	4	4	4	4	4
		Total	(86)	86	73	48	45	39	41
	Fre.	Fast		50	50	50	50	50	50
		Ord.		46	52	68	58	60	60
		Total		96	102	118	108	110	110
	M			2	2	2	4	4	4
	Total			184	177	168	157	153	155
2010 ~ 2015	Pass.	Exp. Mail	(70)	70	64	41	39	37	37
		Local	(12)	12	12	10	8	6	8
		V.P	(4)	4	4	4	4	4	4
		Total	(86)	86	80	55	51	47	48
	Fre.	Fast		60	60	60	60	60	60
		Ord.		58	64	84	71	73	73
		Total		118	124	144	131	133	133
	M			2	2	2	4	4	4
	Total			206	206	201	186	184	185

Notes:
1. The number of train is total of Up and Down trains per day.
2. Pass. Fre, V.P, Ord and M in the "Train" Column are Passenger, Freight, Parcel, Ordinary and Miscellaneous Train, respectively.
3. Since track capacity will be fully occupied after 2010, the number of trains will be the same thereafter.
4. The hatched column shows the passenger train number set at lower levels than the demand for the purpose of saving track capacity to satisfy freight traffic demand until 2010.

Table 2 Number of Train by Year after Construction of the New Corridor 25% UP

(the Section)

Year		Train	DLI–GZB	GZB–KRJ	KRJ–ALJN	ALJN–TDL	TDL–SKB	SKB–ETW	ETW–CNB
2000	Pass.	Exp. Mail	(70)	70	54	37	37	35	35
		Local	(12)	12	12	10	8	4	6
		V.P	(4)	4	4	4	4	4	4
		Total	(86)	86	70	51	49	43	45
	Fre.	Fast		37	37	37	37	37	37
		Ord.		41	47	60	51	53	53
		Total		78	84	97	88	90	90
	M			2	2	2	4	4	4
	Total			166	156	150	141	137	139
2005	Pass.	Exp. Mail	(70)	70	64	44	44	42	42
		Local	(12)	12	12	10	8	4	6
		V.P	(4)	4	4	4	4	4	4
		Total	(86)	86	80	58	56	50	52
	Fre.	Fast		50	50	50	50	50	50
		Ord.		46	52	68	58	60	60
		Total		96	102	118	108	110	110
	M			2	2	2	4	4	4
	Total			184	184	178	168	164	166
2010 ~ 2015	Pass.	Exp. Mail	(70)	70	64	46	52	50	50
		Local	(12)	12	12	10	8	6	8
		V.P	(4)	4	4	4	4	4	4
		Total	(86)	86	80	60	64	60	62
	Fre.	Fast		60	60	60	60	60	60
		Ord.		58	64	84	71	73	73
		Total		118	124	144	131	133	133
	M			2	2	2	4	4	4
	Total			206	206	206	199	197	199

Table 3 Number of Train by Year after Construction of the New Corridor 50% UP

(the Section)

Year		Train	DLI–GZB	GZB–KRJ	KRJ–ALJN	ALJN–TDL	TDL–SKB	SKB–ETW	ETW–CNB
2000	Pass.	Exp. Mail	(70)	70	60	46	46	44	44
		Local	(12)	12	12	10	8	4	6
		V.P	(4)	4	4	4	4	4	4
		Total	(86)	86	76	60	58	52	54
	Fre.	Fast		37	37	37	37	37	37
		Ord.		41	47	60	51	53	53
		Total		78	84	97	88	90	90
	M			2	2	2	4	4	4
	Total			166	162	159	150	146	148
2005	Pass.	Exp. Mail	(70)	70	64	46	55	53	53
		Local	(12)	12	12	10	8	4	6
		V.P	(4)	4	4	4	4	4	4
		Total	(86)	86	80	60	67	61	63
	Fre.	Fast		50	50	50	50	50	50
		Ord.		46	52	68	58	60	60
		Total		96	102	118	108	110	110
	M			2	2	2	4	4	4
	Total			184	184	180	179	175	177
2010 ~ 2015	Pass.	Exp. Mail	(70)	70	64	46	59	57	57
		Local	(12)	12	12	10	8	4	6
		V.P	(4)	4	4	4	4	4	4
		Total	(86)	86	80	60	71	65	67
	Fre.	Fast		60	60	60	60	60	60
		Ord.		58	64	84	71	73	73
		Total		118	124	144	131	133	133
	M			2	2	2	2	2	2
	Total			206	206	206	204	200	202

Table 4 Number of Train by Year after Construction of the New Corridor 75% UP

(the Section)

Year	Train			DLI	GZB	KRJ	ALJN	TDL	SKB	ETW CNB
2000	Pass.	Exp. Mail		(70)	70	64	46	54	52	52
		Local		(12)	12	12	10	8	4	6
		V.P		(4)	4	4	4	4	4	4
		Total		(86)	86	80	60	66	60	62
	Fre.	Fast			37	37	37	37	37	37
		Ord.			41	47	60	51	53	53
		Total			78	84	97	88	90	90
	M				2	2	2	4	4	4
	Total				166	166	159	158	154	156
2005	Pass.	Exp. Mail		(70)	70	64	46	59	57	57
		Local		(12)	12	12	10	8	4	6
		V.P		(4)	4	4	4	4	4	4
		Total		(86)	86	80	60	75	65	67
	Fre.	Fast			50	50	50	50	50	50
		Ord.			46	52	68	58	60	60
		Total			96	102	118	108	110	110
	M				2	2	2	4	4	4
	Total				184	184	180	183	179	181
2010 ~ 2015	Pass.	Exp. Mail		(70)	70	64	46	59	57	57
		Local		(12)	12	12	10	8	4	6
		V.P		(4)	4	4	4	4	4	4
		Total		(86)	86	80	60	71	65	67
	Fre.	Fast			60	60	60	60	60	60
		Ord.			58	64	84	71	73	73
		Total			118	124	144	131	133	133
	M				2	2	2	4	2	2
	Total				206	206	206	206	202	204

Table 5 Number of Train by Year after Construction of the New Corridor 100% UP

(the Section)

Year	Train			DLI	GZB	KRJ	ALJN	TDL	SKB	ETW CNB
2000	Pass.	Exp. Mail		(70)	70	64	46	59	57	57
		Local		(12)	12	12	10	8	4	6
		V.P		(4)	4	4	4	4	4	4
		Total		(86)	86	80	60	71	65	67
	Fre.	Fast			37	37	37	37	37	37
		Ord.			41	47	60	51	53	53
		Total			78	84	97	88	90	90
	M				2	2	2	4	4	4
	Total				166	166	159	163	159	161
2005	Pass.	Exp. Mail		(70)	70	64	46	59	57	57
		Local		(12)	12	12	10	8	4	6
		V.P		(4)	4	4	4	4	4	4
		Total		(86)	86	80	60	71	65	67
	Fre.	Fast			50	50	50	50	50	50
		Ord.			46	52	68	58	60	60
		Total			96	102	118	108	110	110
	M				2	2	2	4	4	4
	Total				184	184	180	183	179	181
2010 ~ 2015	Pass.	Exp. Mail		(70)	70	64	46	59	57	57
		Local		(12)	12	12	10	8	4	6
		V.P		(4)	4	4	4	4	4	4
		Total		(86)	86	80	60	71	65	67
	Fre.	Fast			60	60	60	60	60	60
		Ord.			58	64	84	71	73	73
		Total			118	124	144	131	133	133
	M				2	2	2	4	4	4
	Total				206	206	206	206	202	204

2-10 Train Diagram Pattern (New Corridor)

Train Number Ratio between DLI-AGC and AGC-CNB Sections

	DLI ∿ AGC	∿ CNB
S. Express 250 km/h	5	3
L. Express 160 km/h	2	1

$$N = \frac{H \times 60 \times \varepsilon}{h} \times A$$

$$= \frac{(24-4) \times 60 \times 0.8}{92} \times 7$$

$$\fallingdotseq 73$$

N = Track capacity
H = Time zone for train operation (excluding 4 hours for maintenance work)
ε = Track use ratio ... 0.8
h = Period required per pattern (min)
A = Train number per pattern
—— S. Exp. Train
━━ L. Exp. Train

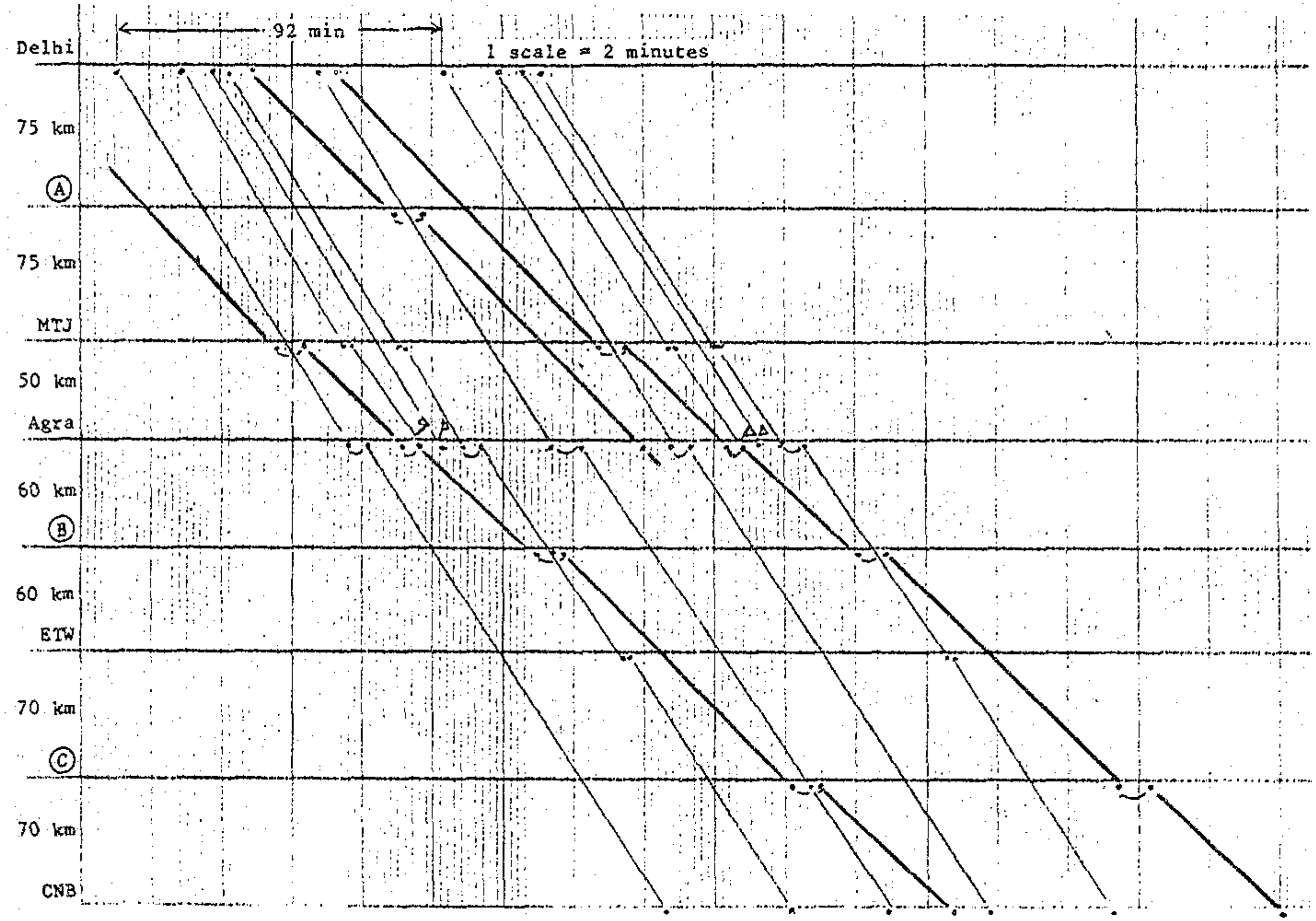


Fig. 1 Train Diagram Pattern (New Corridor)

Train Number Ratio between DLI-AGC and AGC-CNB Sections

	DLI ∿ AGC	AGC ∿ CNB
S. Express 250 km/h	4	3
L. Express 160 km/h	2	1

$$N = \frac{H \times 60 \times f}{h} \times A$$

$$= \frac{(24-4) \times 60 \times 0.8}{79} \times 6$$

$$\doteqdot 73$$

N = Track capacity
H = Time zone for train operation (excluding 4 hours for maintenance work)
f = Track use ratio ... 0.8
h = Period required per pattern (min)
A = Train number per pattern
— = S. Exp. Train
▬ = L. Exp. Train

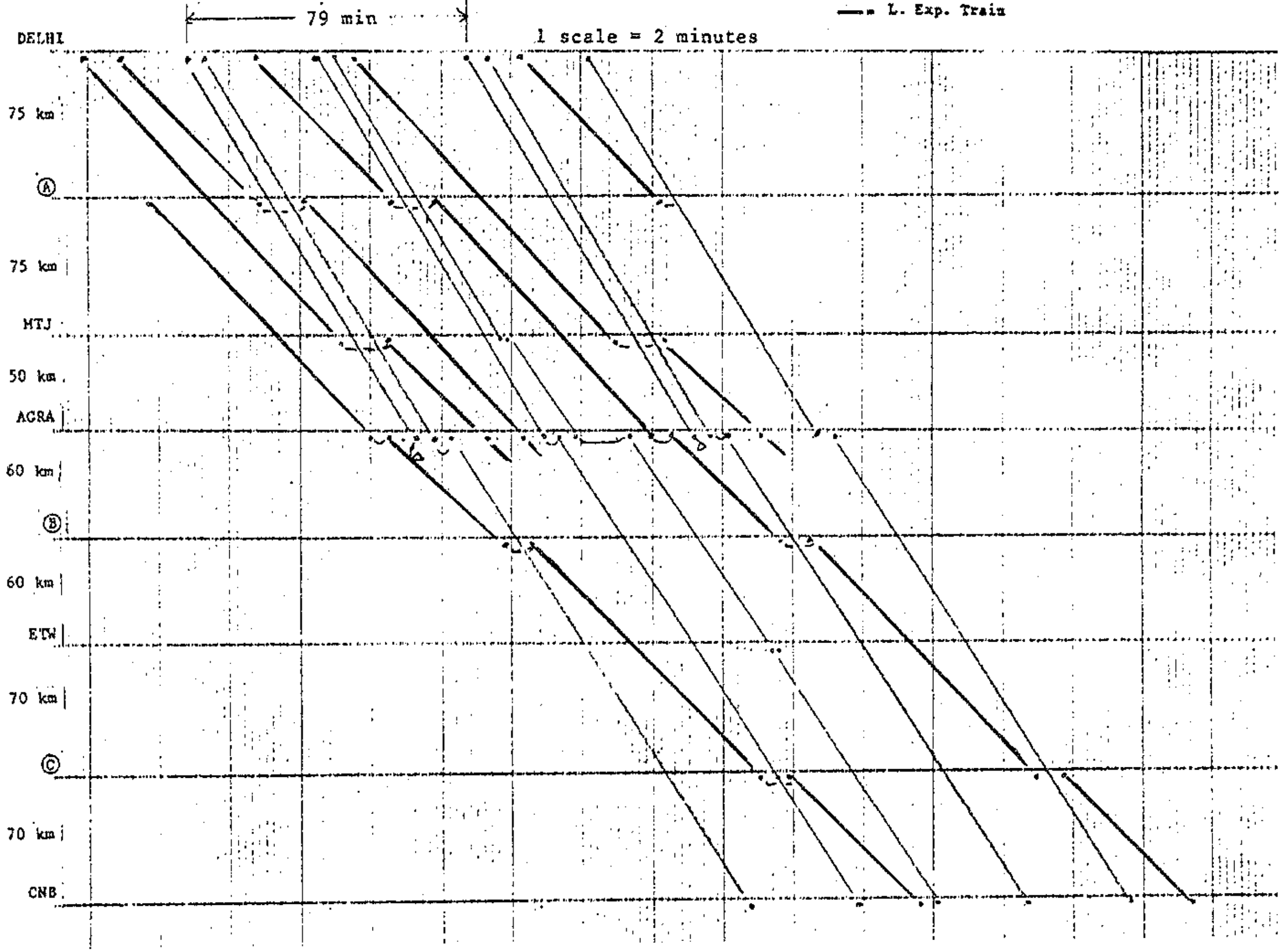


Fig. 2 Train Diagram Pattern (New Corridor)

Train Number Ratio between
DLI-AGC and AGC-CNB Sections

	DLI ~ AGC	~ CNB
S. Express 250 km/h	9	7
L. Express 160 km/h	2	1

$$N = \frac{H \times 60 \times f}{h} \times A$$

$$= \frac{(24-4) \times 60 \times 0.8}{139} \times 11$$

$$\doteq 76$$

N = Track capacity
H = Time zone for train operation
(excluding 4 hours for maintenance work)
f = Track use ratio ... 0.8
h = Period required per pattern (min)
A = Train number per pattern
—— = S. Exp. Train
▬▬ = L. Exp. Train

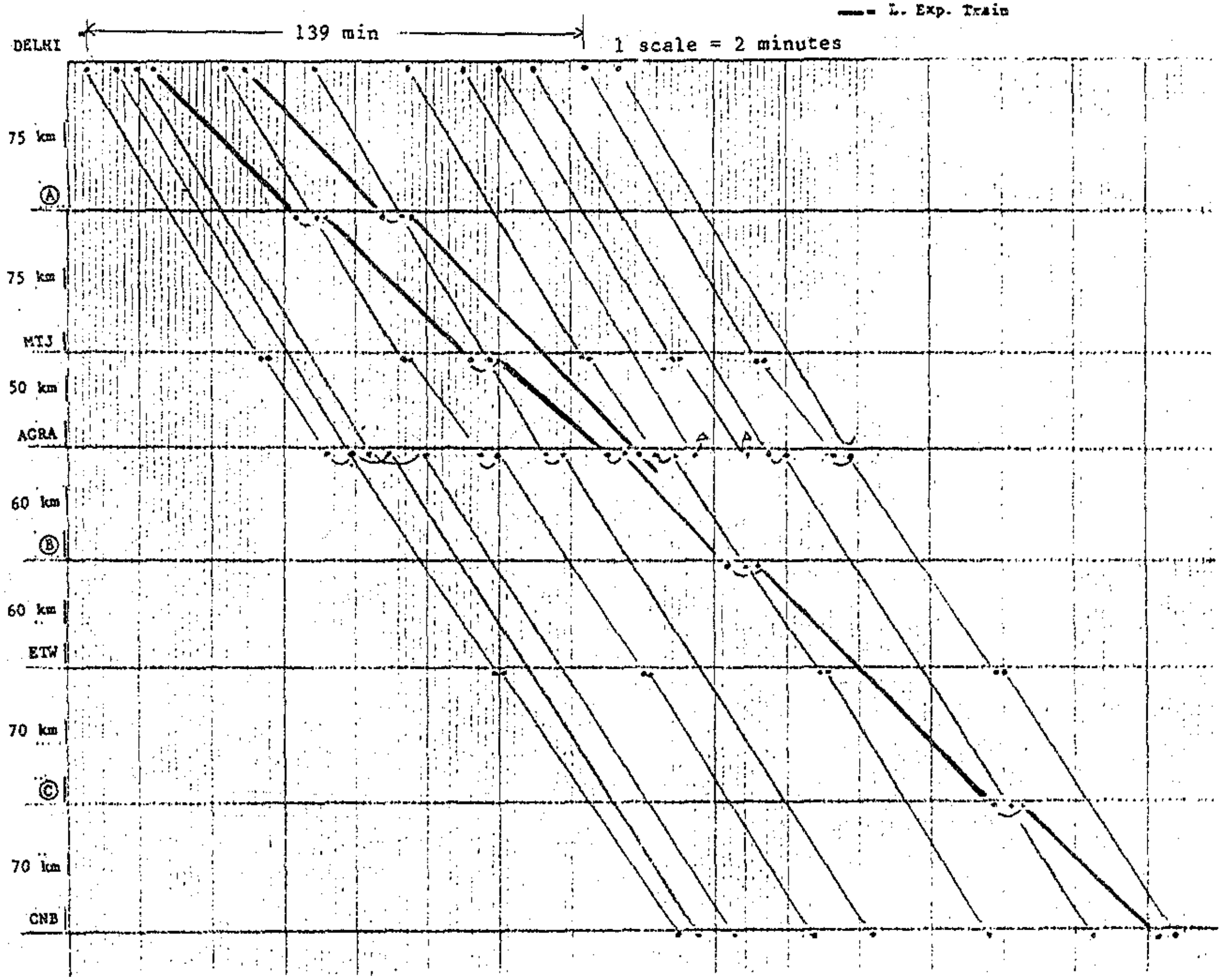


Fig. 3 Train Diagram Pattern (New Corridor)

Train Number Ratio between DLI-AGC and AGC-CNB Sections

	DLI ~ AGC	~ CNB
S. Express 250 km/h	18	15
L. Express 160 km/h	2	1

$$N = \frac{H \times 60 \times f}{h} \times A$$

$$= \frac{(24-4) \times 60 \times 0.8}{245} \times 20$$

$$\doteqdot 78$$

N = Track capacity
H = Time zone for train operation (excluding 4 hours for maintenance work)
f = Track use ratio ... 0.8
h = Period required per pattern (min)
A = Train number per pattern
—— = S. Exp. Train
━━ = L. Exp. Train

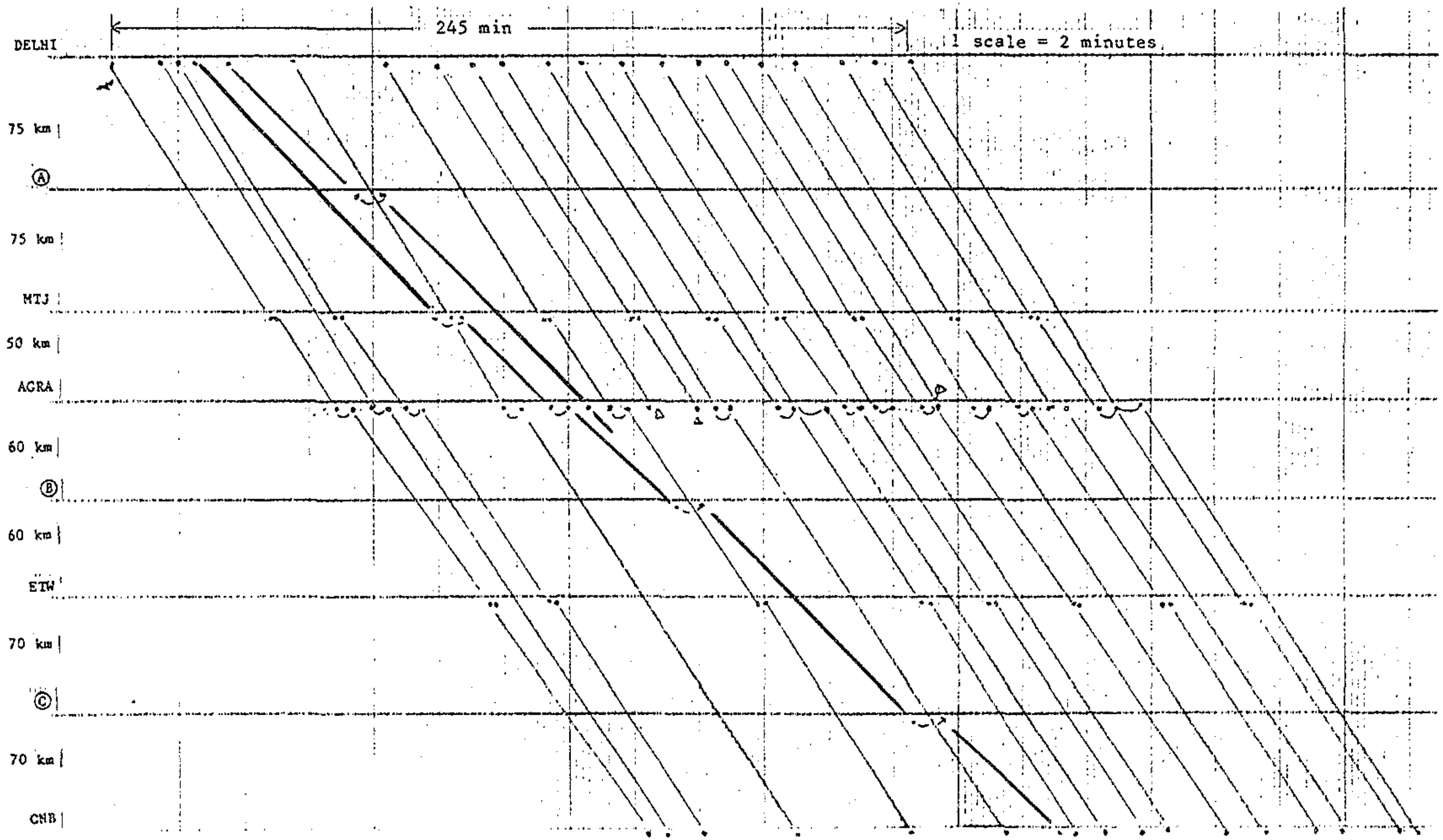


Fig. 4 Train Diagram Pattern (New Corridor)

2-11 The Conditions of Arrival and Departure Track Utilization and their Respective Capacity at Main Stations

The conditions of utilization of arrival and departure tracks and their respective capacity at the Delhi, New Delhi, Tundla and Kanpur stations are as follows:

The time used is according to the 1986-10-1 Working Time Table (NORTHERN RAILWAY).

The following conditions are also assumed as premises.

. The track occupation chart at respective stations shall be used for the computation.

. In counting the number of trains, any train shall be counted as "one" train when it goes into an arrival track or leaves from a departure track.

. The time for using the arrival and departure tracks shall be the total of the stopping time plus 5 minutes for advancing into the arrival track or leaving from the departure track.

. The precise capacity of the arrival and departure tracks can be calculated on the basis of the actual train diagram and track occupation chart. This time, however, it shall be obtained through a rough calculation method used as the standard for studying improvement of facilities.

(1) Delhi Station

1) Present state of platform tracks

There are 16 platform tracks. Four tracks (Tracks No. 13 - 16) are dead-end tracks with their accommodation capacity being relatively small, 8-11 coaches. In addition, for 8 tracks (Tracks No. 3-12), simultaneous arrival and departure of two trains of short formation (with 12-15 coaches each) and a train of long formation are made possible by using two tracks divided to use the same platform.

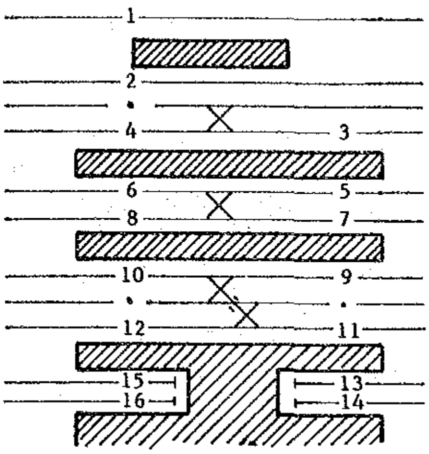


Fig. 1 Present State of Platform Tracks

Table 1 No. of Coaches that can be Accommodated at the Platforms

Platform track	No. of coaches that can be accommodated	Platform track	No. of coaches that can be accommodated
1	17	9	15
2	18	10	12
3	14	11	14
4	14	12	14
5	14	13	10
6	14	14	8
7	14	15	11
8	13	16	11

2) State of the use of platform tracks

The number of arrival and departure trains, utilization time and usage rates for the respective platforms are shown in Table 2.

As for the main arrival and departure tracks (Track No. 1 - No. 12), the average utilization time for a train is 103 minutes and the average use rate of platform tracks is 57%.

Table 2 No. of Arrival and Departure Trains, Utilization Time and Usage Rates for the Respective Tracks

Platform No.	No. of trains	Utilization time (min.) 0-24:00 Ⓐ	Utilization time (min.) 4:30-22:30 Ⓑ	Average utilization time for a train (min.) Ⓐ	Average utilization time for a train (min.) Ⓑ	Usage rate (%) Ⓐ÷1440 x100	Usage rate (%) Ⓑ÷1080 x100
1	12	767	667	64		53	62
2	8	645	580	81		45	54
[3	12	780	675	65		54	63
4	5	1,147	862	229		80	80
[5	[5.5] 8	770	770	96		53	71
6	[4.5] 7	855	855	122		59	79
[7	[5] 6	735	735	123		51	68
8	[7] 8	815	590	102		57	55
[9	[7.5] 9	870	675	97		60	63
10	[6.5] 8	840	715	105		58	66
[11	[8.5] 9	675	655	75		47	61
12	[13.5] 14	865	805	62		60	75
Subtotal	[95] (106)	(9,764)	(8,584)	(103)	*1(102)	(57)	(66)
13	7	780		111		54	
14	1	110		110		8	
15	3	460		153		32	
16	3	395		132		27	
Subtotal	(14)	(1,745)		(124)		(30)	
Total	120	11,509		(96)		(50)	

Note: 1. The mark [in the platform No. column indicates the single platform which is used by two lines.

2. The figures [ ] in the no-of-trains column show the number of trains counted in such a way that the train simultaneously using 2 lines is counted as 0.5 trains.

3. The figures marked with *1 result from calculations based on the assumption that the number of trains between 4:30 - 22:30 is 84.

3) No. of arrival and departure trains that can be accommodated at platforms

Assuming that the main time zone for the arrival and departure of passenger trains is between 4:30 and 22:30 (18 hours), the number of coaches that can arrive at or depart from the platforms calculated for the 12 main tracks (Tracks No. 1-12) is as follows. The maximum platform use rate is 75%.

a. In the case that the platform use time for one train is assumed to be 103 minutes just as at present, the arrival and departure of 11 more trains will be possible.

$$N = \frac{\text{(Time zone for arrival and departure of trains x 60 x Platform use rate x No. of platform tracks) - (Present utilization time)}}{\text{Average utilization time for a train}}$$

$$= \frac{(18(Hr)x60x0.75x12)-8584(min.)}{103(min.)} \doteqdot 11 \text{ (trains)}$$

b. If, considering that a passenger train length will be expanded to 18-21 coaches in the future, 5 tracks for the arrival and departure of more than 18 coaches are secured (for instance, Nos. 1, 2, 3-4, 5-6 and 7-8) while the 4 other (Nos. 9-12) tracks are used for the arrival and departure of short trains as at present, the number of arrival and departure tracks will become insufficient even with the present number of trains. Therefore, it is necessary to reduce the stopping time.

$$N = \frac{(18(Hr)x60x0.75x9)-8584(min.)}{103\ (min.)} \doteqdot \Delta 12 \text{ (trains)}$$

c. In cases where the stopping time is assumed to be 20 minutes, 30 minutes, and 40 minutes.

(a) In the case of a stopping time of 20 minutes.

$$N = \frac{(18(Hr)x60x0.75x9)}{20+5+5} \doteqdot 243 \text{ (trains)}$$

(b) In the case of stopping time of 30 minutes

$$N = \frac{(18(Hr)x60x0.75x9)}{30+5+5} \doteqdot 182 \text{ (trains)}$$

(c) In the case of stopping time of 40 minutes (almost the same number as at present in New Delhi)

$$N = \frac{(18(Hr) \times 60 \times 0.75 \times 9)}{40+5+5} \doteqdot 145 \text{ (trains)}$$

Currently on tracks No. 1-12, the total number of arrival and departure trains a day is 95 (84 trains during the period between 4:30 - 22:30). Assuming that the stopping time is about the same as that for the present New Delhi Station (145 trains - 84 trains = 61 trains), the addition of trains between Delhi - Kanpur (about 50 trains, bothway, in the year 2000) is basically possible partly because the New Delhi Station will be also used.

Regarding the steps for the above, a review of the plan for using terminals of both Delhi and New Delhi stations, expansion of platforms, improvement or laying of storage tracks, raising coach utilization efficiency, etc., are presumably needed.

(2) New Delhi Station

1) Present state of platform tracks

Platform tracks total 11. Of them, 2 tracks (Track No. 10-11) are dead end tracks, and the number of coaches that can be accommodated here is 16-slightly fewer than the 18-22 trains for tracks No. 1-9.

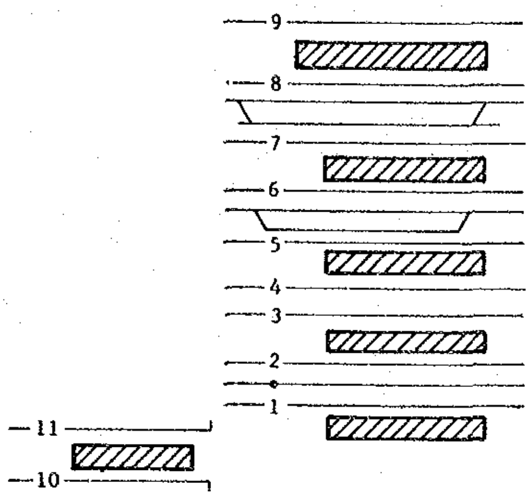


Fig. 2 Present State of Platform Tracks

Table 3 No. of Coaches that can be Accommodated at Platforms

Platform track	No. of coaches that can be accommodated	Platform track	No. of coaches that can be accommodated
1	18	7	22
2	18	8	22
3	18	9	22
4	22	10	16
5	22	11	16
6	22		

2) State of utilization of platform tracks

The number of arrival and departure trains, utilization time, and use rate for respective platform tracks are as shown in Table 4.

Taking the example of the main arrival and departure tracks (Tracks No. 1-9), the average utilization time for one train is 50 minutes, with the use rate of platform tracks being 48%.

Table 4 No. of Arrival and Departure Trains, Utilization Time, and Use Rates for Respective Tracks

Platform No.	No. of trains	Utilization time (min.)		Average utilization time for a train (min.)		Usage rate (%)	
		0-24:00 Ⓐ	4:30-22:30 Ⓑ	Ⓐ	Ⓑ	Ⓐ÷1440 x100	Ⓑ÷1080 x100
1	19	905	765	48		63	71
2	21	745	650	35		52	60
3	25	760	760	31		53	70
4	13	770	770	59		53	71
5	10	670	670	67		47	62
6	8	480	460	60		33	43
7	8	605	605	76		42	56
8	10	549	549	55		38	51
9	11	715	715	65		50	66
Subtotal	(125)[112]	(6,199)	(5,944)	(50)	(52)	(48)	(61)
10	2	103		52		7	
11	3	390		130		27	
Subtotal	(5)	(493)		(99)		(17)	
Total	130	6,692		(52)		(42)	

3) No. of arrival and departure trains that can be accommodated at respective platforms

Assuming that the main arrival and departure time zone for passenger trains is between 4:30 and 22:30 (18 hours), the number of arrival and departure trains that can be accommodated by 9 main tracks (Tracks No.1-9) computed on a trial basis are as follows:

a. In the case that the platform utilization time for a train is assumed to be 50 minutes as at present, the arrival and departure of about 26 more trains will be possible.

$$N = \frac{(18(Hr)x60x0.75x9)-5944}{50} \fallingdotseq 26 \text{ (trains)}$$

b. In the case that the stopping time is assumed to be 20 minutes and 30 minutes:

a) In the case of stopping time of 20 minutes

$$N = \frac{(18(Hr)x60x0.75x9)}{20(min.)+(5+5)(min.)} \doteqdot 243 \text{ (trains)}$$

b) In the case of stopping time of 30 minutes

$$N = \frac{(18(Hr)x60x0.75x9)}{30(min.)+(5+5)(min.)} \doteqdot 182 \text{ (trains)}$$

Currently, on tracks No. 1-9, the number of arrival and departure trains per day is 125 (112 trains between 4:30 and 22:30). Based on the present stopping time, the arrivals and departures of about 26 trains are possible, so there is somewhat more room than in the case of Delhi Station.

(3) Kanpur Station

1) Present state of platform tracks

There are 6 platform tracks. Of these six, one (track No. 8) is a dead end track, while the No. 3 track is also used as a long-term storage track.

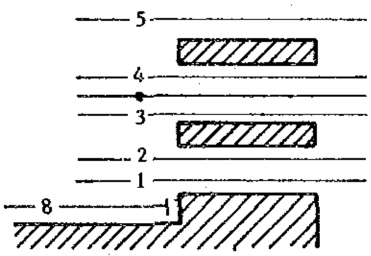


Fig. 3 Present State of Platform Tracks

Table 5 No. of Coaches that can be Accommodated at Respective Platforms

Platform track	No. of coaches that can be accommodated	Platform track	No. of coaches that can be accommodated
1	17	4	17
2	16	5	18
3	13	8	12

(Note) No. 8 track is a dock platform.

2) State of utilization of platform tracks

The number of departure and arrival trains, utilization time and use rates for respective platform tracks are as shown in Table 6.

Table 6 No. of Arrival and Departure Trains, Utilization Time and Use Rates for the Respective Tracks

Platform No.	No. of trains	Utilization time Ⓐ (min.)	Average utilization time for a train (min.)	Use rate (%) Ⓐ ÷ 1440 x 100
1	21	755	36	52
2	17	695	41	48
4	15	630	42	44
5	14	885	61	62
Subtotal	(67)	(2,965)	(44)	(51)
3	8	955	119	62
8	6	855	143	59
Subtotal	(14)	(1,810)	(129)	(63)
Total	81	4,775	(59)	(55)

As for the main arrival and departure tracks (Tracks No. 1, 2, 4 and 5), the average utilization time for a train is 44 minutes, and the average platform use rate is 51%.

3) No. of arrival and departure trains that can be accommodated at respective platforms.

Results of the trial computation for 4 main tracks (Tracks No. 1, 2, 4 and 5) are as shown below.

Since the train setting time zone is not strictly limited, the platform utilization time is assumed to be 60%.

a. In the case that the platform utilization time for a train is set at 44 minutes as at present, the arrival and departure of about 11 more trains than at present will be possible.

$$N = \frac{(24(\text{Hr})x60x0.6x4(\text{tracks})-2,965(\text{min.})}{44(\text{min.})} \doteqdot 11 \text{ (trains)}$$

b. Since Kanpur plans the establishment of platform tracks, the arrival and departure of about 39 trains will become possible if the utilization time for one train is assumed to be 44 minutes.

$$N = \frac{(24(\text{Hr})x60x0.6x2(\text{tracks}))}{44(\text{min.})} \doteqdot 39 \text{ (trains)}$$

In the year 2000, an increase of about 50 trains (both way) from the present level is anticipated. The additional accommodation capacity requirement will be met with the present capacity for 11 trains and the capacity for 39 trains to be created by the year 2000.

(4) Tundla Station

1) *Present state of platform tracks*

There are 4 platform tracks. For tracks No. 2 and 3, improvement of signalling facilities is planned under the 7th Five Year Plan.

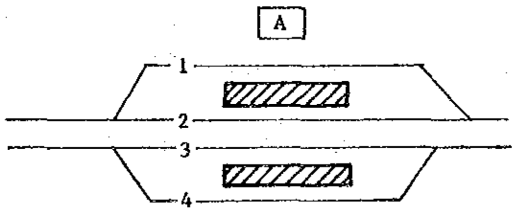


Fig. 4 Present State of Platforms

Table 7 No. of Coaches that can be Accommodated at Platform Tracks

Platform tracks	No. of coaches that can be accommodated
1	6
2	17
3	18
4	14

Note 1: Track No. 1 is a dock platform.

2) State of use of platform tracks

The numbers of arrival and departure trains, utilization time, and use rates for respective platform tracks are shown in Table 8.

Table 8 No. of Arrival and Departure Trains, Utilization Time, and Use Rates for the Respective Tracks

Platform No.	No. of trains	Utilization time Ⓐ (min.)	Average utilization time for a train (min.)	Use rate (%) Ⓐ ÷ 1440 x 100
1	3	620	207	43
2	22	607	28	42
3	25	762	31	53
4	17	705	42	49
Total	67	2,694	(41)	(47)

3) No. of arrival and departure trains that can be accommodated at platforms

a. In the case that the average stopping time for a train is assumed to be 41 minutes as at present, the arrival and departure of about 18 more trains will be possible (the platform use rate is assumed to be 60%).

$$N = \frac{(24(Hr)x60x0.6x4(tracks))-2,694(min.)}{41(min.)} \fallingdotseq 18 \text{ (trains)}$$

b. In the case that the stopping time of a train is assumed to be 10 minutes, 15 minutes, or 20 minutes:

(a) In the case of stopping time of 10 minutes

$$N = \frac{(24(Hr)x60x0.6x4(tracks))}{10(min.)+(5+5)(min.)} \doteqdot 172 \text{ (trains)}$$

(b) In the case of stopping time of 15 minutes:

$$N = \frac{(24(Hr)x60x0.6x4(tracks))}{15(min.)+(5+5)(min.)} \doteqdot 138 \text{ (trains)}$$

(c) In the case of stopping time of 20 minutes:

$$N = \frac{(24(Hr)x60x0.6x4(tracks))}{20(min.)+(5+5)(min.)} \doteqdot 115 \text{ (trains)}$$

About 50 more trains (both way) are expected in the year 2000. Since the present number of trains is about 50, it is necessary to set the average stopping time for a train at about 20 minutes.

2-12 Status of the Current Train Flow (Exp/Mail) (The Section)

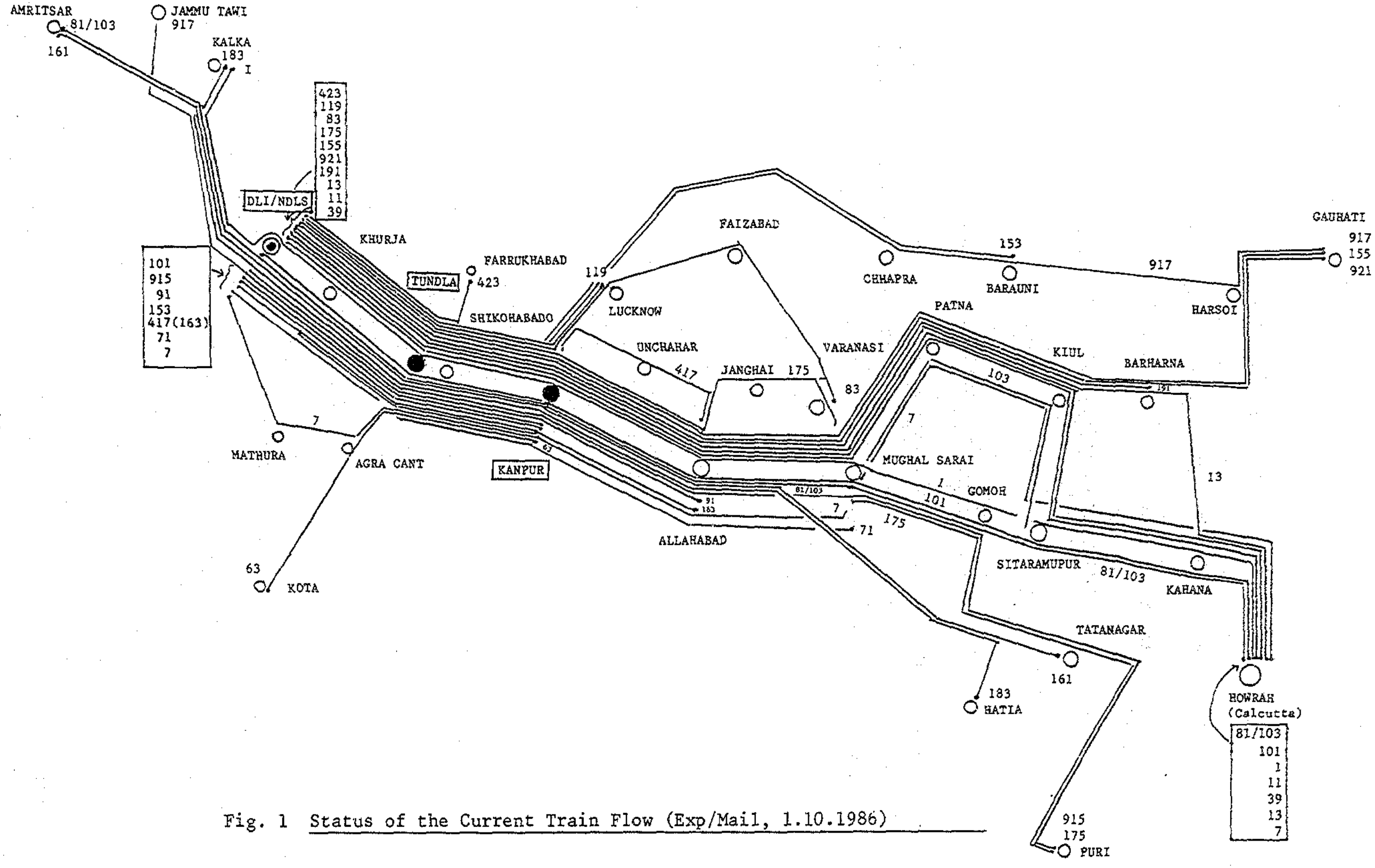
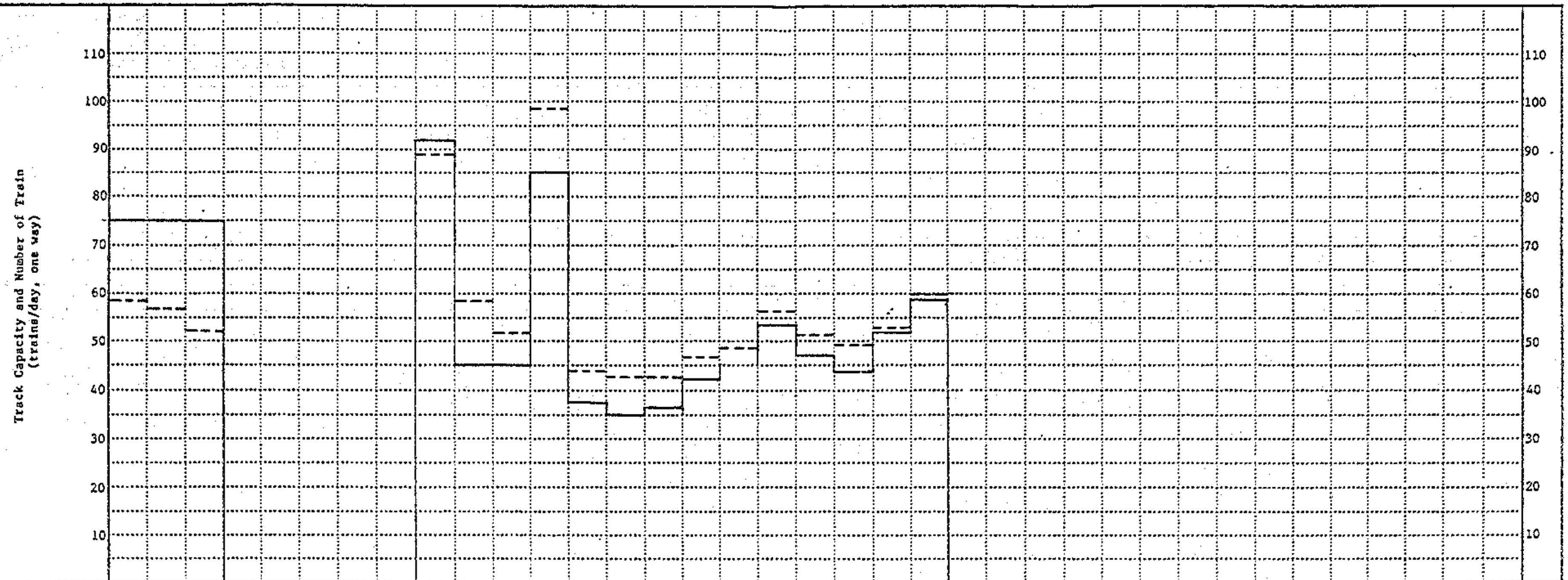


Fig. 1 Status of the Current Train Flow (Exp/Mail, 1.10.1986)

2-13 Track Capacity and Number of Train (one way) (1985)



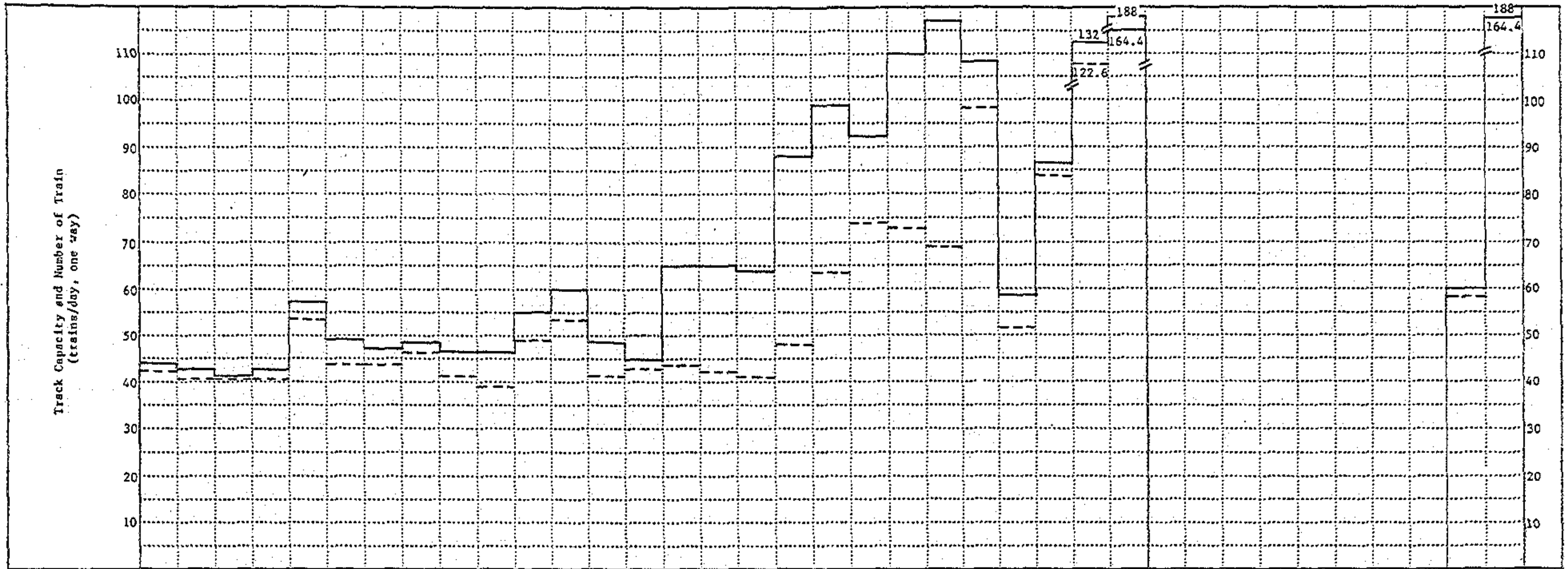
DISTANCE	F.H.	1452.23	1446.21	1442.97	1439.07	1457.95	1455.07	1442.26	1439.07	1432.35	1398.02	1369.82	1326.52	1263.22		1248.51	1212.02	1028.55	1021.15	1019.75
	I.b.	6.02	3.24	3.90		2.88	12.81	3.19	6.72	34.33	28.20	43.30	63.30	14.71	(1.10)	36.49	183.47	7.40	1.40	
No. of Train	PASS.I.S.	39.5	32.75	32.5		57	20.5	20.5	53	25	24	24	24	25	31	27	25	25	33	
	FREIGHT	18.8	24.3	19.4		37.3	37.2	31	50.4	18	18	18	25.5	23	24	23.5	23.5	26	26	
	DEPART	0.2	0.2	0.2		0.2	-	-	0.3	0.6	0.6	0.6	0.7	0.7	0.7	1	0.8	1	1	
	TOTAL	58.5	57	52.1		94.5	57.7	51.5	103.7	43.6	42.6	42.6	47.2	48.7	55.7	51.5	49.3	52	60	
Track capa.		75	75	75		96	45	45	90	37	35	36	42	45	54	47	44	51	59	

STATION		
DLI	DELHI	
DSA	DELHI SHAHDARA	
	(A)PANEL JN.	
SBB	SAHIBABADO	
NDLS	NEW DELHI	
TKJ	TILAK BRIDGE	
	(B)PANEL	
SBB	SAHIBABADO	
GZB	GHAZIABADO	
DKDE	DANKAUR	
KRJ	KHURJA JN.	
ALJN	ALIGARH JN.	
BRN	BARHAN JN.	
TDL	TUNDLA JN.	
	TUNDLA EAST SIDING	
SKB	SHIKOHABADO JN.	
PNK	PANKI	
GMC	G.M.C. YARD	
CNB	KANPUR CENTRAL	

. PASS.I.S. : PASSENGER INCLUDING SUBURBAN
. DEPART : DEPARTMENTAL
. Track capa: Track capacity
. ———— : Track capacity
. — — — : Number of Train

. F.M : From Howrah
. I.b : In between

Fig. 1 DLI/NDLS ～ CNB



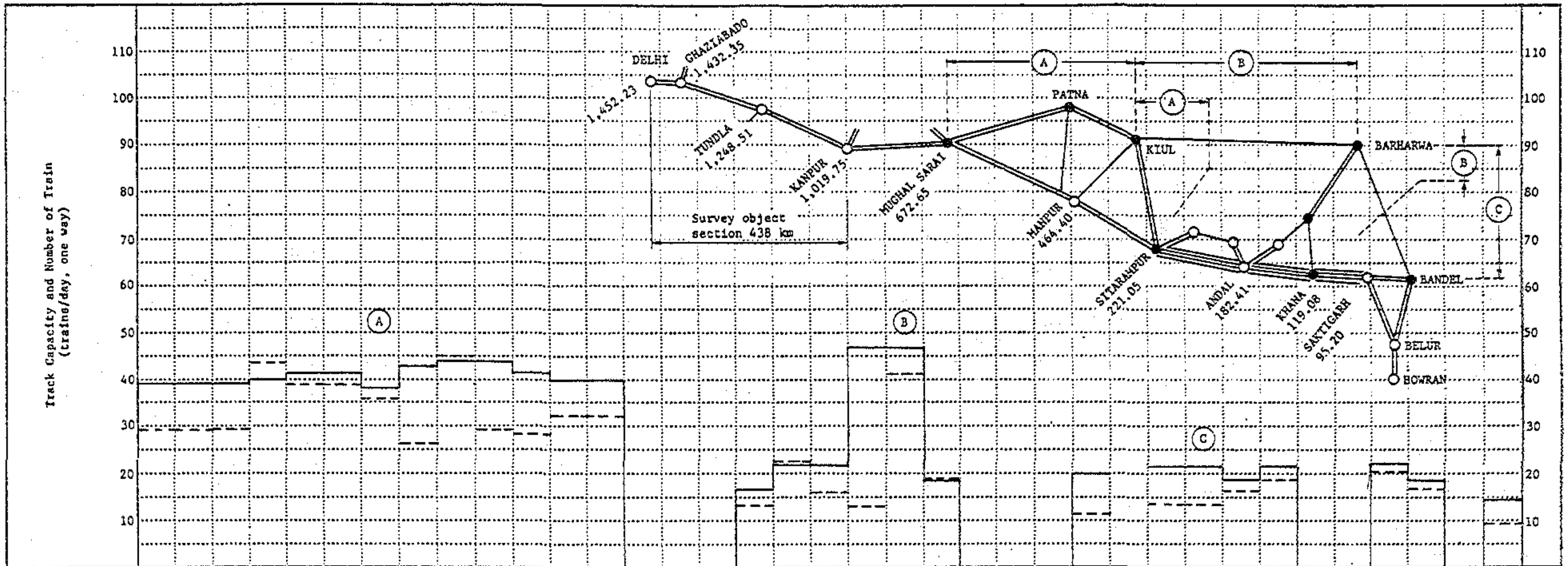
Station		DISTANCE F.H.	DISTANCE I.b.	No. of Train PASS.I.S.	No. of Train FREIGHT	No. of Train DEPART.	No. of Train TOTAL	Track capa.
CNB	KARPUR CENTRAL	1019.75	11.61	19	22.5	0.9	42.4	44
CHK	CHAKERI	1008.14	65.95	19	21.5	0.9	41.4	43
FTP	FATEHPUR	942.19	99.21	18	21.5	0.9	40.4	42
MRE	MANAURI	842.98	17.44	18	22.5	0.9	41.4	43
ALD	ALLAHABAD	825.54	7.48	28	24	0.9	52.9	57
NYN	NAINI	818.06	1.41	20	23.5	0.9	44.4	49
COI	CHHEOKI	816.65	80.8	19	25	0.9	44.9	47
MZP	MIRZAPUR	735.85	31.08	20	24.5	0.9	45.4	48
CAR	CHUNAR	704.77	24.31	15	25.5	0.9	41.4	46
JEP	JEONATHPUR	680.46	7.81	14	25	0.9	39.9	46
MGS	MUGHAL, SARAI JN.	672.65	117.85	11	37.5	1	49.5	55
DOS	DEHRI-ON-SONE	554.80	5.76	15	37.5	1	53.5	60
SEB	SON NAGAR JN.	549.04	79.46	13	26.3	1	40.3	48
GAYA	GAYA JN.	494.64	169.49	14	27.7	1	42.7	45
GMO	GOMOH JN.	300.15	29.27	14	28.7	1	43.7	65
DHN	DHANBAD JN.	270.88	9.57	17	24.2	1	42.2	65
PKA	PRADHAN KHUNTA JN.	261.31	5.85	15	24.1	1	40.1	64
CAM	CHHOTA AMBANA	255.46	34.41	15	32.4	1	48.4	88
STN	SITARAMPUR JN.	221.05	8.93	28	33.9	2	63.9	99
ASN	ASANSOL LN.	212.12	25.71	30	43.2	1	74.2	91
UDL	ANDAL JN.	182.41	66.53	32	39.9	1	72.9	110
KAN	KHANA JN.	119.88	13.15	44	24.5	1	69.5	117
BWN	BURDWAN	106.73	11.53	68	27.6	2	97.6	108
SKG	SAKTIGARH	95.20	65.91	40	9.9	1	50.9	59
BDC	BANDEL	39.29	17.14	80	3.5	1	84.5	86
SHE	SEORAPHULI JN.	22.15	15.58	117	4.6	1	122.6	132
BEQ	BELUR	6.57	6.57	149	13.4	2	164.4	188
HWH	HOWRAH	0						

Station		DISTANCE F.H.	DISTANCE I.b.	No. of Train PASS.I.S.	No. of Train FREIGHT	No. of Train DEPART.	No. of Train TOTAL	Track capa.
SKG	SAKTIGARH	82.88	76.31	37	17.8	1	55.8	60
BEQ	BELUR	6.57	6.57	149	13.4	2	164.4	188
HWH	HOWRAH							

. PASS.I.S. : PASSENGER INCLUDING SUBURBAN
. DEPART : DEPARTMENTAL
. Track capa: Track capacity
. ———— : Track capacity
. — — — : Number of Train

. F.H : From Howrah
. I.b : In between

Fig. 2 CNB ~ HWH



DISTANCE (KM)		MGS	DLN	ARA	DNR	PNC	BKP	MKA	TALL	RDUM	KIUL	JAJ	JSME	MDP	STN
DISTANCE (KM)	F.H	755.35	697.45	592.65	553.25	533.64	498.14	454.36	449.58	442.57	420.35	366.43	322.50	293.54	221.05
	I.b	57.90	104.80	39.4	19.61	35.5	43.78	4.78	7.01	22.22	53.92	43.93	28.96	72.49	
No. of Train	PASS.I.S.	19	19	20	25	28	28	24	18	29	18	18	19	19	
	FREIGHT	8.1	8.1	8.2	17.8	9.8	9.8	10.8	7.5	14.5	10.8	8.3	12.6	12.6	
	DEPART.	1	1	1	1	1	1	1	1	1	1	1	1	1	
	TOTAL	28.1	28.1	29.2	43.8	38.8	38.8	35.1	26.5	44.5	29.8	27.3	32.6	32.6	
Track capa.		39	39	39	40	41	41	38	42	43	43	41	40	40	
STATION		MUGHAL SARAI	DILDARNAGAR	ARA JN.	DANAPUR	PATNA SAHEB	BAKHTIYARPUR	MOKAMA JN	TALL	RAMPUR DUMRA	KIUL JN	JHAJHA	JASIDIH JN	MADHUPUR	SITARAMPUR

← D →

DISTANCE (KM)		KIUL	JMP	SBG	BHW		SNT	KAN
	I.b	45.05	127.08	54.80	4.84	101.20	71.0	
No. of Train	PASS.I.S.	11	14	11	8	18	12	
	FREIGHT	2	7.6	5.1	4.8	22.3	11.9	
	DEPART.	-	0.6	0.4	0.5	1	0.5	
	TOTAL	13	22.2	16.5	13.3	41.3	24.4	
Track capa.		17	22	22	46	46	24	
STATION		KIUL JN	JAMALPUR	SAHIBGANJ	BARHARWA	CABIN SBG. LOOP LINK	SAINTHIA	KHANA

← S → ← D → ← S →

DISTANCE (KM)		BHW	BDAG	TDLE	DCLE	ACLE	KWF	BDC
	I.b	4.73		79.25		72.74	104.70	
No. of Train	PASS.I.S.	6		12	12	14	14	
	FREIGHT	5.6		1.1	1.1	1	3.6	
	DEPART.	0.2		1	1	1	1	
	TOTAL	11.8		14.1	14.1	16	18.6	
Track capa.		20		21	21	19	21	
STATION		BARHARWA	BONIDANGA	TIL DANGA	DHULIAN GANGA	AZIMGANJ	KATWA	BANDEL

← S →

DISTANCE (KM)		TOLE	NFK	MLDT	NFK	DGLE
	I.b	6.91	34.8		14.78	
No. of Train	PASS.I.S.	9	8		7	
	FREIGHT	11.7	8.5		0.4	
	DEPART.	0.7	0.7		1	
	TOTAL	21.4	17.2		8.4	
Track capa.		22	19		14	
STATION		TIL DANGA	NEW FARAKKA	MALDA TOWN	NEW FARAKKA	DHUUAN GANGA

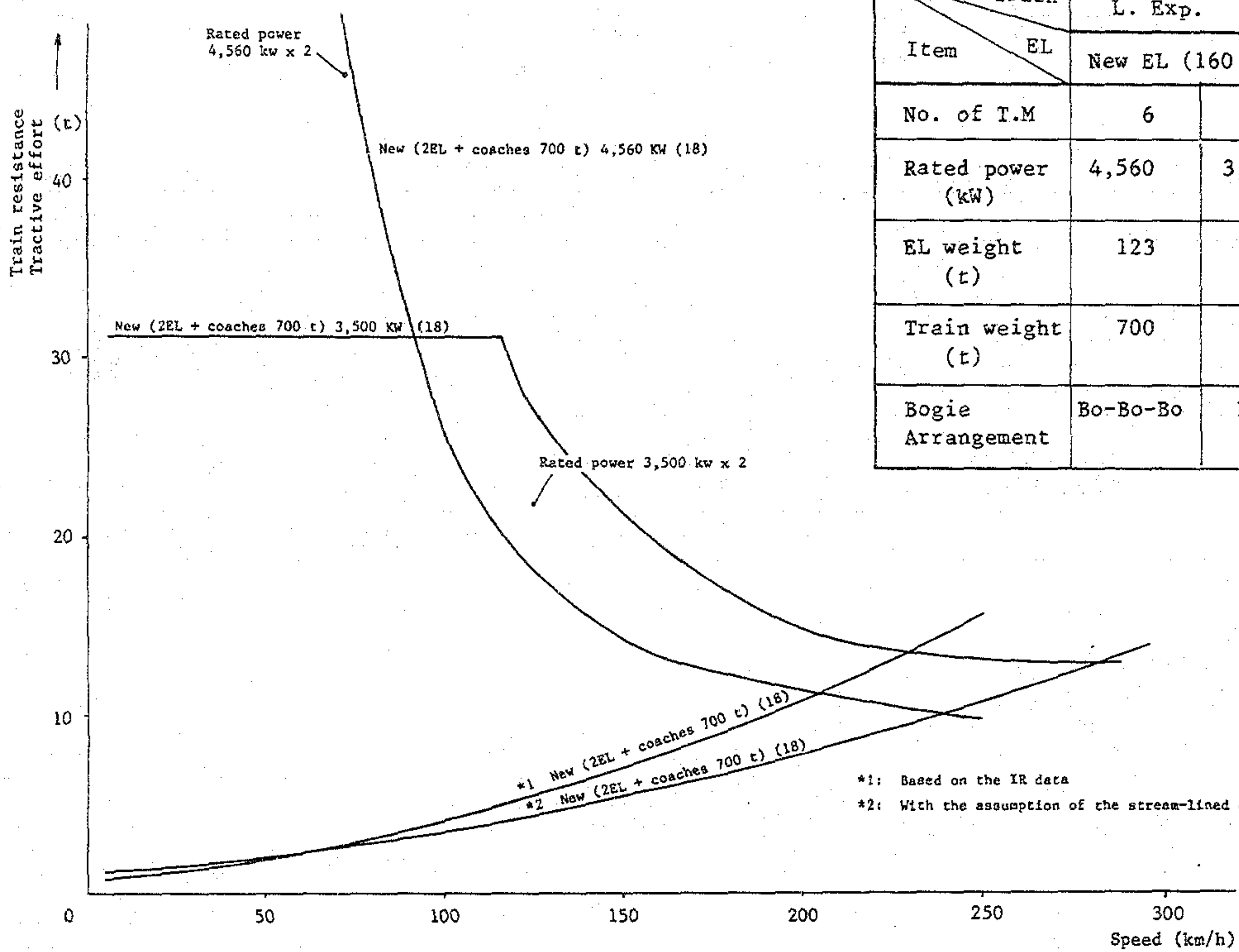
← S →

- PASS.I.S. : PASSENGER INCLUDING SUBURBAN
- DEPART : DEPARTMENTAL
- Track capa: **Track capacity**
- ——— : Track capacity
- — — — : Number of Train

- D: Double track
- S: Single track
- F.H : From Howrah
- I.b : In between

Fig. 3 MGS ~ STN, KIUL ~ KAN, BHW ~ BDC, TOLE ~ DGLE

3-1-(1) Speed vs. Tractive Effort and Train Resistance Curve of L. Exp. Trains on the Section



(Level)

Item \ Train / EL	L. Exp. New EL (160 km/h)	
No. of T.M	6	4
Rated power (kW)	4,560	3,500
EL weight (t)	123	78
Train weight (t)	700	700
Bogie Arrangement	Bo-Bo-Bo	Bo-Bo

The rated power (P) of the traction motor (TM) is set with consideration given to the increase in allowable temperature. It is indicated in the following formula:

$$P = \frac{1}{1000} N E_t I \eta \text{ (Kw)}$$

Here, N: No. of TM

Et: Terminal voltage of TM

I: Current of TM

η: Efficiency

The actual power, however, can generally be raised to 50% more than the rated power in consideration of the coefficient of adhesion and the allowable, short-period overcurrent value (a shorter service life due to temperature increase should be remembered, using the rule of halving of the service life with each increase of 6°C or 8°C).

In view of the higher outdoor temperature in India, however, power up to 1.2 times the rated power can be used in the case of 4,560 KW EL as seen in an attached table.

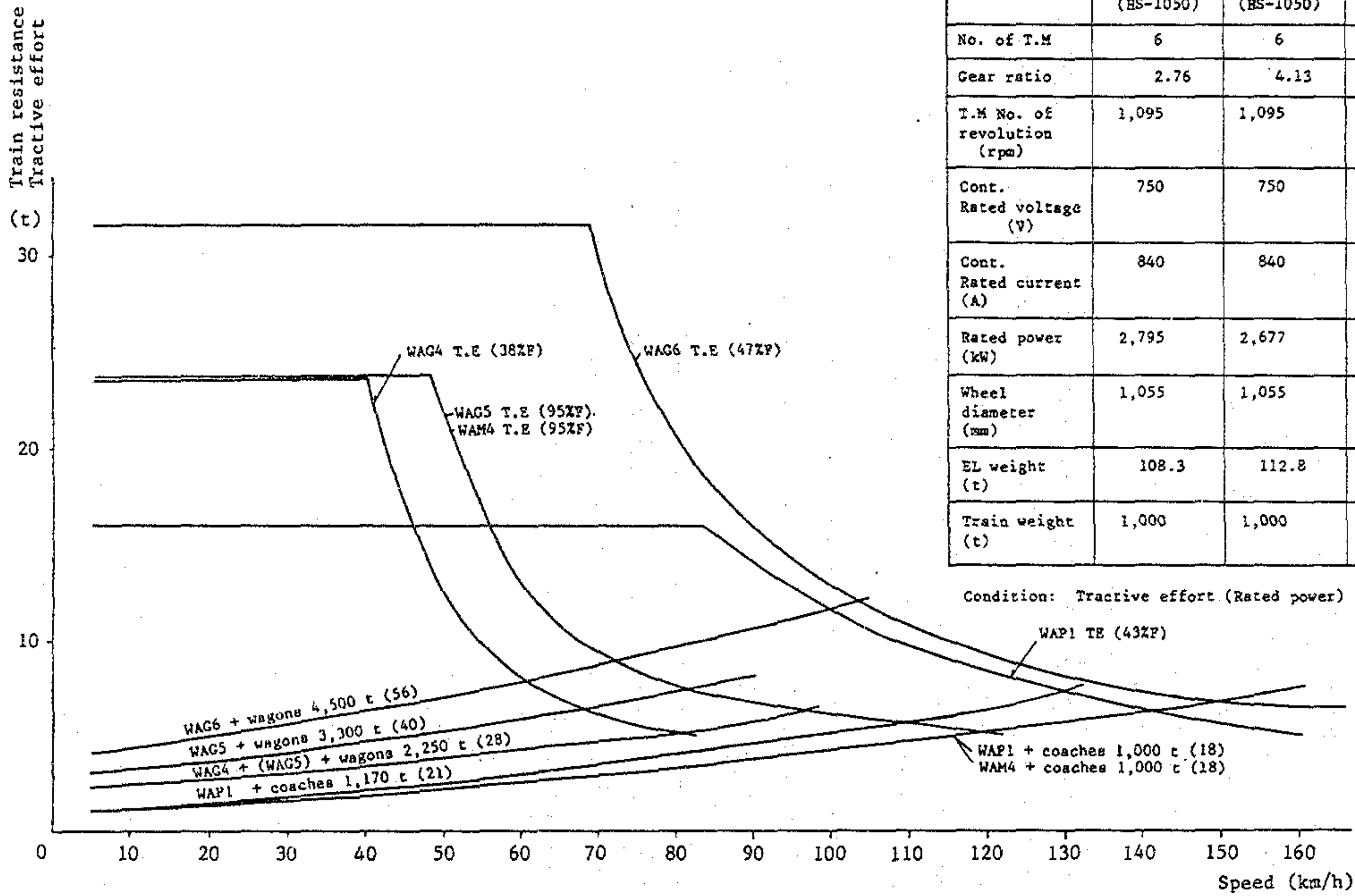
In the case of the 3,500 KW EL, the 3-phase asynchronous power system with excellent readhesion characteristics are used, and commutator and armature winding are eliminated, therefore it is assumed that power amounting to 1.4 times the rated power will be possible.

3-1-(2) Speed vs. Tractive Effort and Train Resistance Curve of Other Trains on the Section

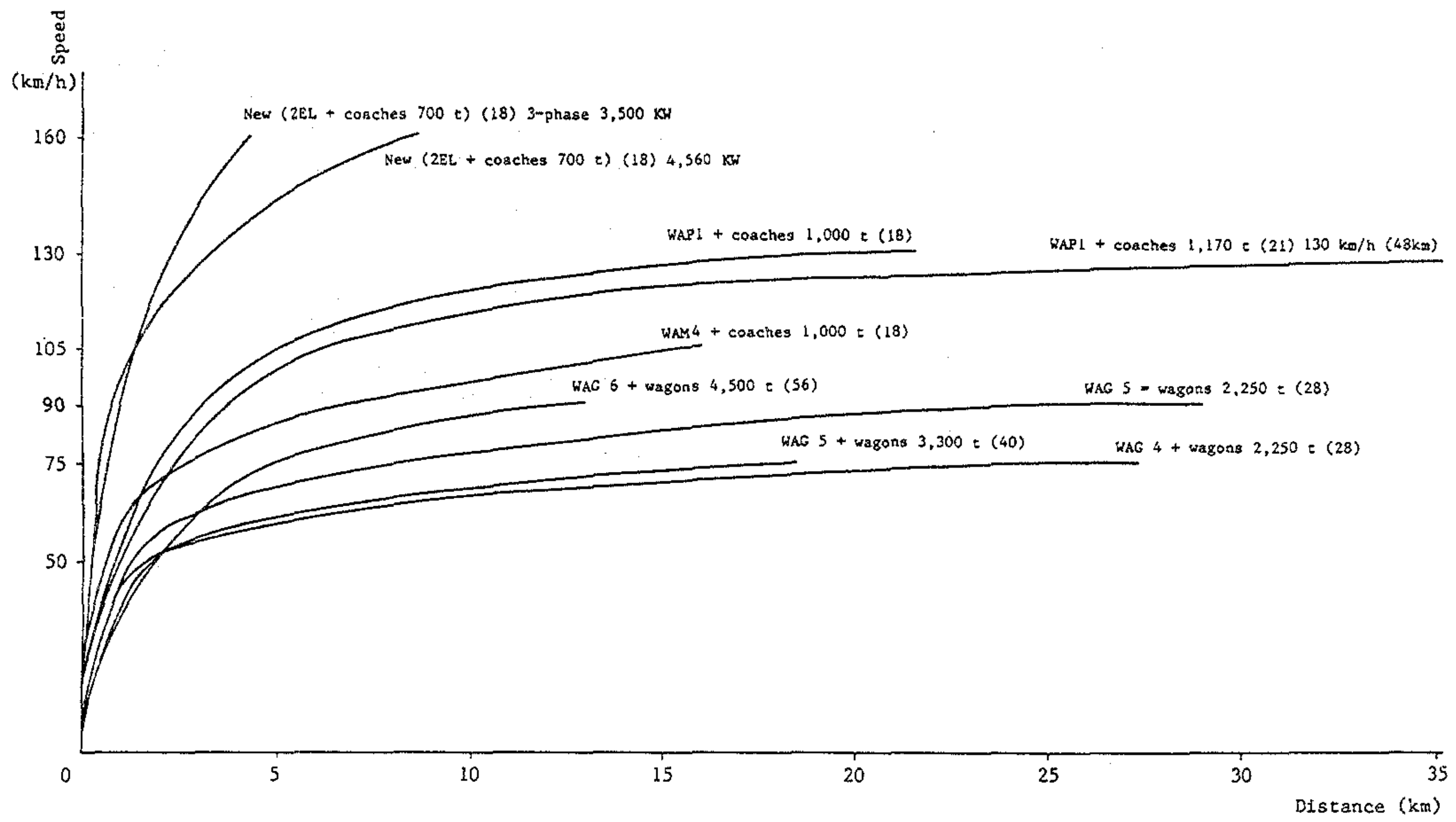
(Level)

Item \ EL \ Train	Exp./Mail Pass.	Local Pass.	Fast	Ordinary Freight
	WAP1	WAM4	WAG6	WAG4
T.M type	TAO-659 (HS-1050)	TAO-659 (HS-1050)		MG-1580 (MG-710)
No. of T.M	6	6	6	2
Gear ratio	2.76	4.13	3.94	3.95
T.M No. of revolution (rpm)	1,095	1,095	970	680
Cont. Rated voltage (V)	750	750	850	1,270
Cont. Rated current (A)	840	840	960	1,000
Rated power (kW)	2,795	2,677	4,560	2,324
Wheel diameter (mm)	1,055	1,055	1,102	*1,102
EL weight (t)	108.3	112.8	123	87.6
Train weight (t)	1,000	1,000	4,500	2,250

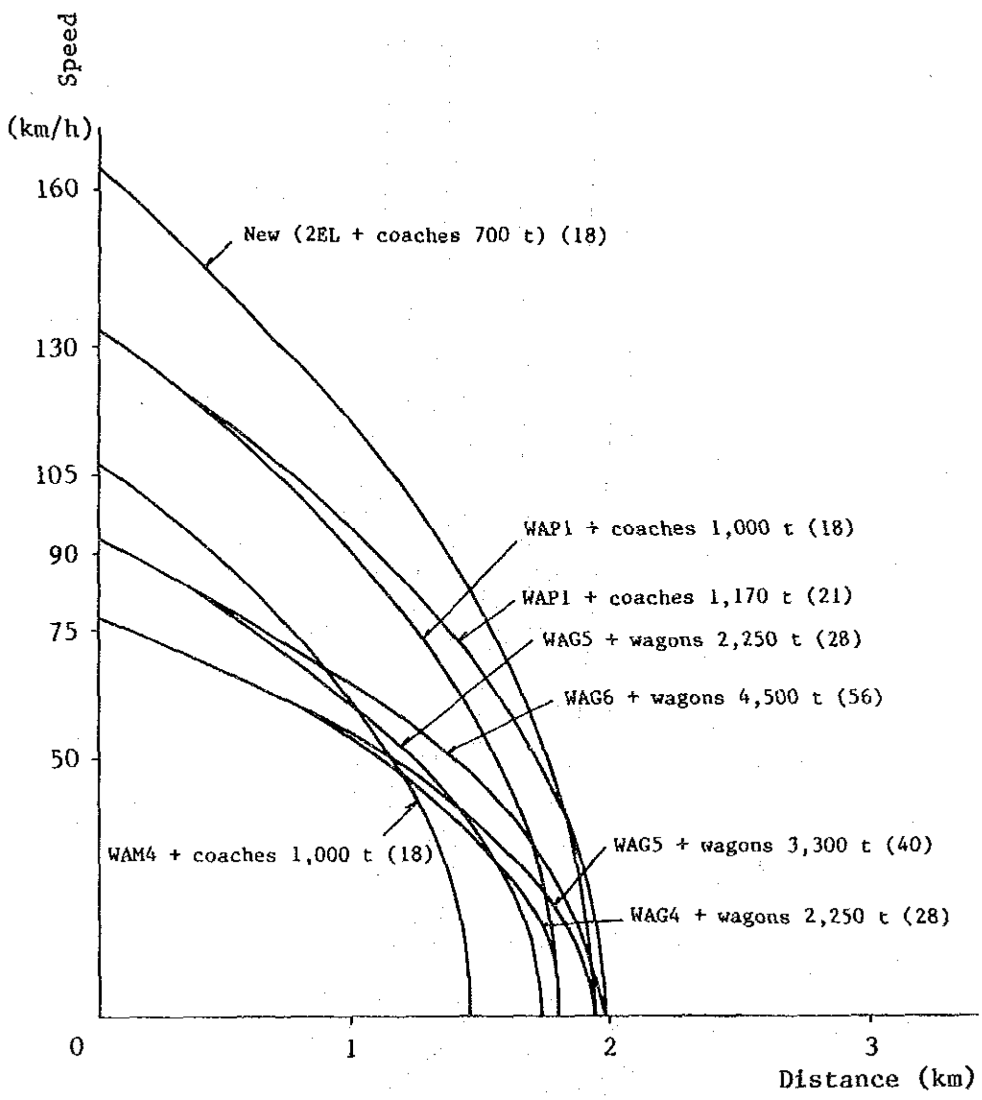
Condition: Tractive effort (Rated power)



3-2 Speed vs. Distance Curve of Trains on the Section (Powering)



3-3 Speed vs. Distance Curve of Trains on the Section (Braking)



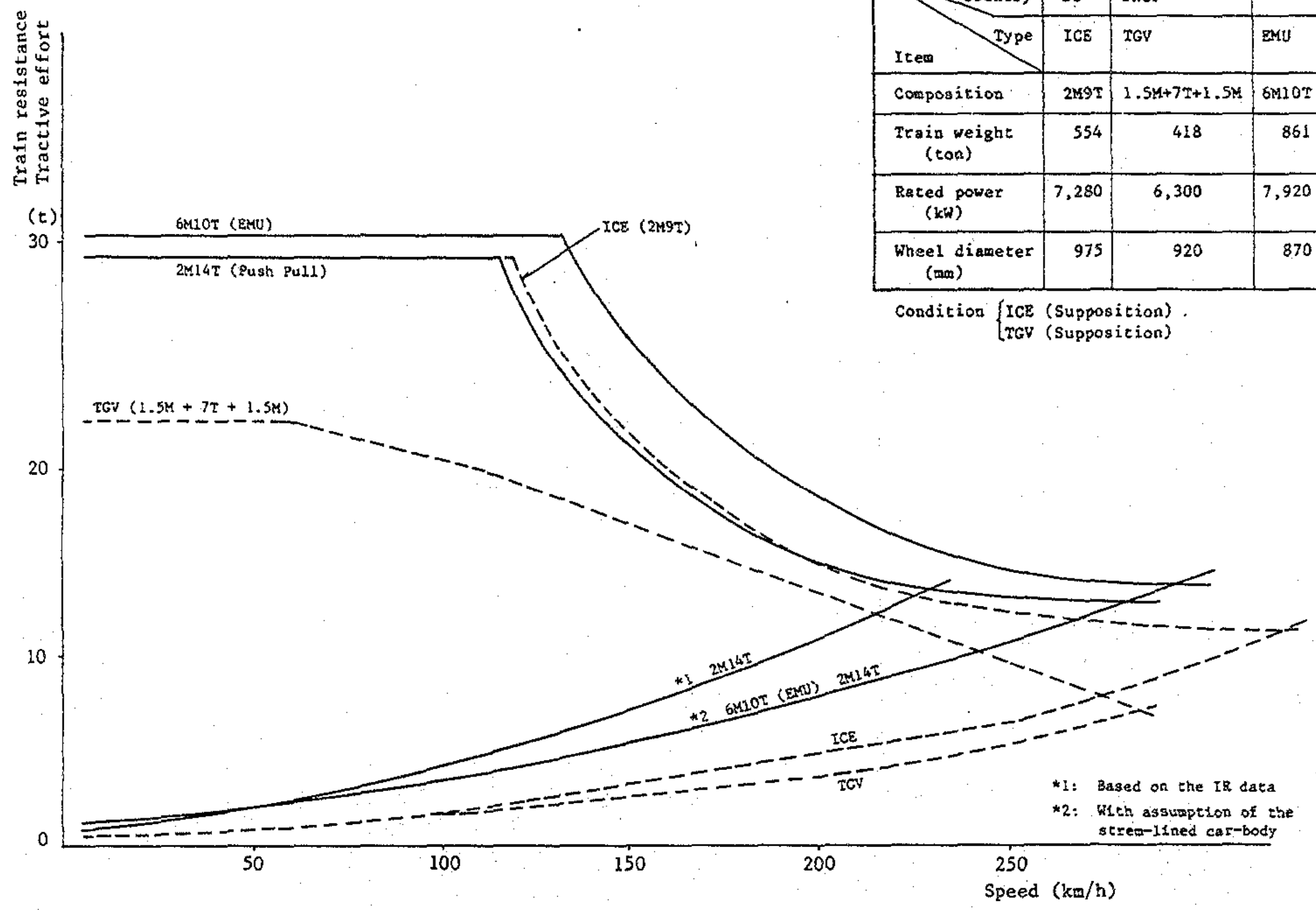
3-4 Comparison of the High Speed Train Characteristics

Item \ Country	Germany DB	France SNCF	Japan JR			Note
			Shinkansen			
Type of EMU	ICE	TGV	Series 0	Series 100	Series 200	
Composition	2M9T	1.5M + 7T + 1.5M	16 M	12M4T	12 M	
Carrying capacity (passengers)	432	386	1,342	1,277	885	
Train length (m)	276	200	400	402	300	
Train weight (ton)	554	383 418	892 970	845 922	697 759	Tare Weight of loaded car
Max. axle weight (ton)	20	16.8 16	16	15.3 13.9	16.4	M T
Max. speed (km/h)	250	270	220	230	240	Operation
Rated power (kW)	3,640 × 2 7,280	525 × 6 × 2 6,300	185 × 4 × 16 11,840	230 × 4 × 12 11,040	230 × 4 × 12 11,040	Continuous
Room: Seat pitch (mm)		972 864	1,160 940	1,160 1,040	1,160 940	First-class Ordinary
Room: Corridor width (mm)		400 400	640 600	600 600	600 600	First-class Ordinary
Noise level dB (A)		90 ∿ 95	Under 80	Under 80	Under 80	
Acceleration (km/h/s)	1.86	1.76 0.60 0.20	0.96 0.25	1.60 0.40 0.25	1.60 0.40 (240km/h) 0.13	5 km/h 210 km/h 260 km/h
Braking distance (m)		260 km/h → 0 3,700	210 km/h → 0 3,000	230 km/h → 0 3,840	230 km/h → 0 4,100	Weight of loaded car and full service
Carring capacity per passenger Power (kW/pass.) Weight (ton/pass.)	 16.9 1.28	 16.3 0.99	 8.8 0.66	 8.6 0.66	 12.5 0.79	
Consumption energy (Wh/passenger.km)		43	33	28	34	
Transport service		1984 16 43	1985 136 373		1985 31 85	Million passengers/year Thousand passengers/day
Train cost per passenger	173	166	78	100	152	

3-5 Speed vs. Tractive Effort and Train Resistance Curve of Trains on the New Corridor

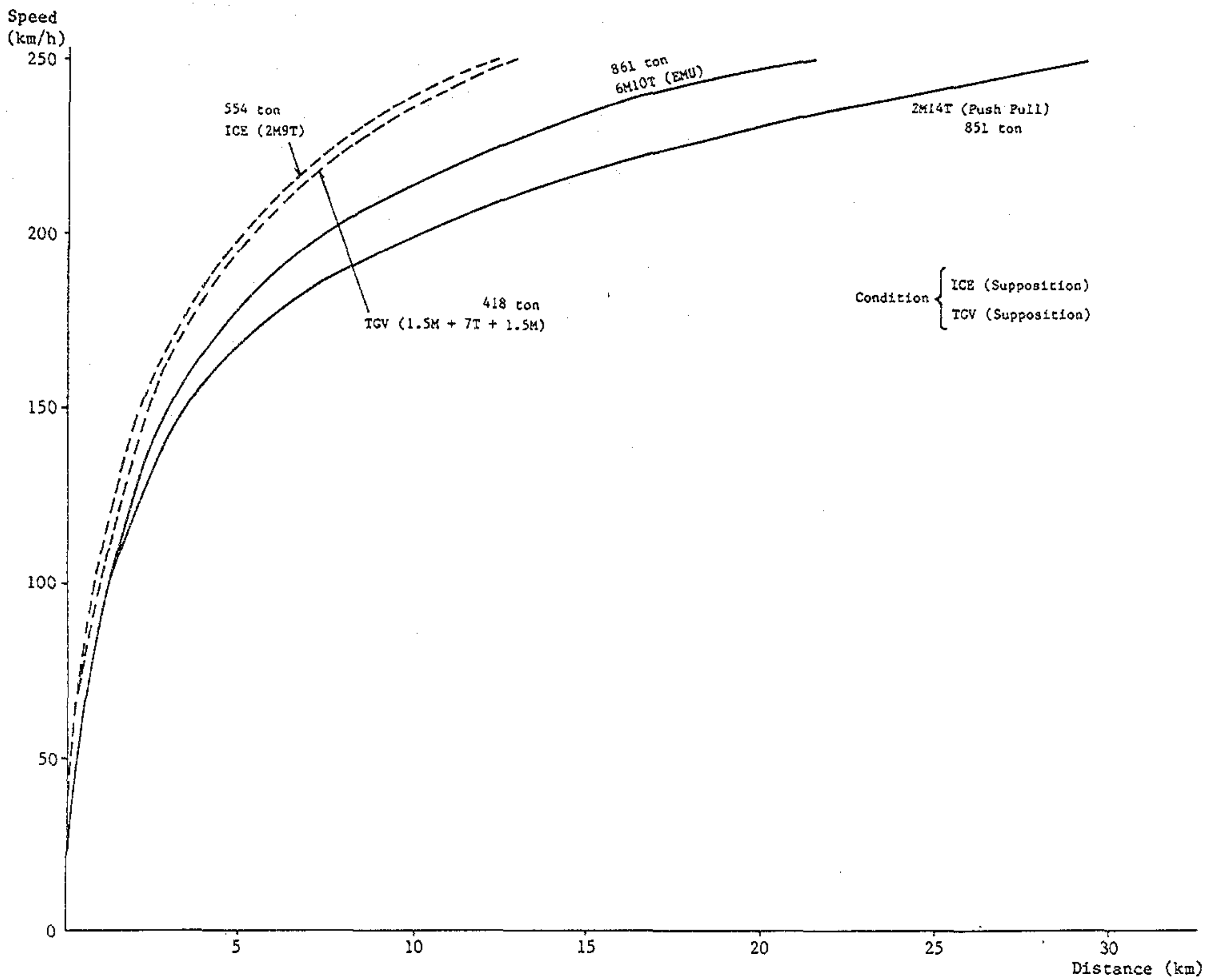
Item \ Country / Type	DB	SNCF	IR	
	ICE	TGV	EMU	Push Pull
Composition	2M9T	1.5M+7T+1.5M	6M10T	2M14T
Train weight (ton)	554	418	861	851
Rated power (kW)	7,280	6,300	7,920	7,000
Wheel diameter (mm)	975	920	870	870

Condition {ICE (Supposition) . TGV (Supposition)

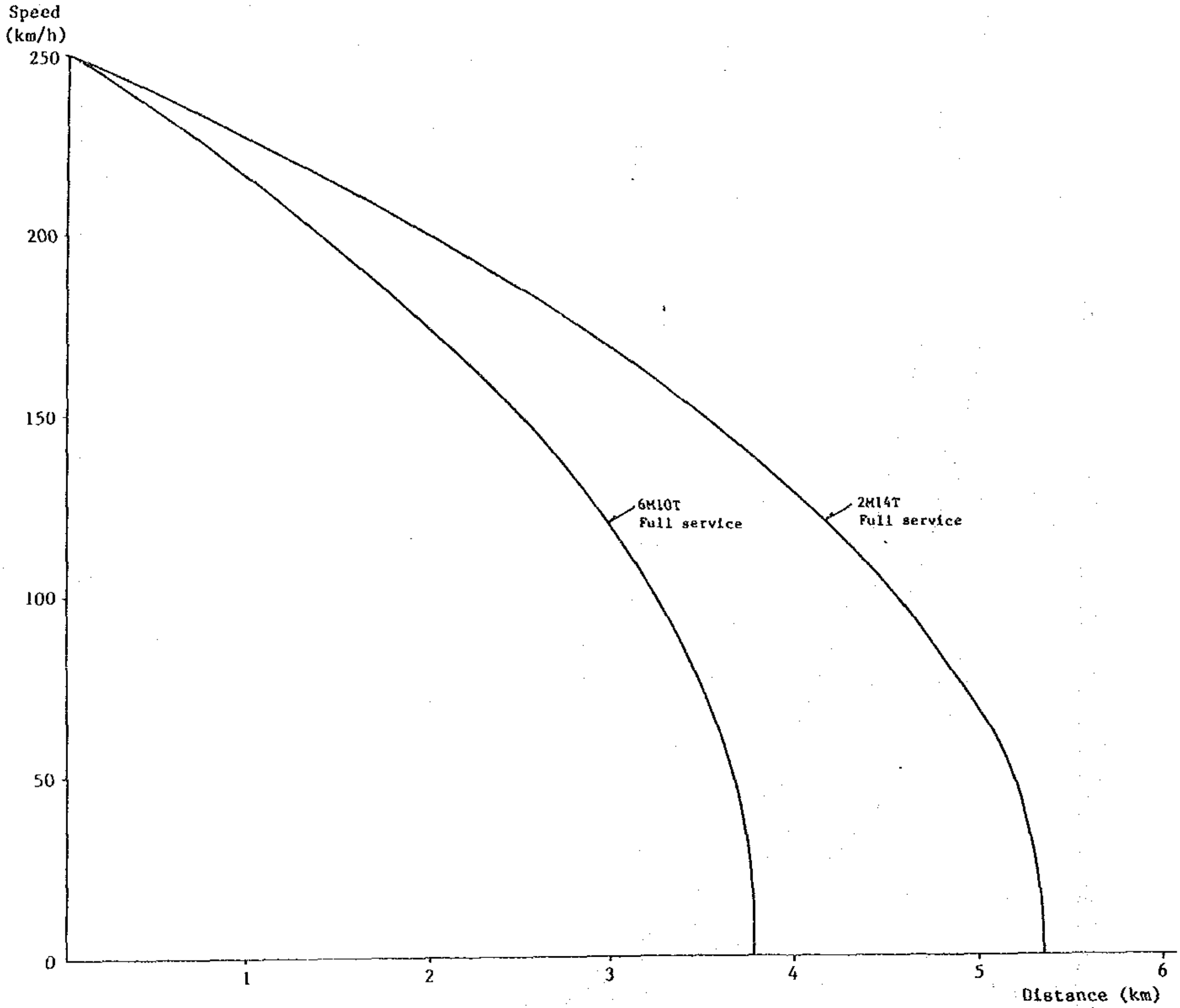


*1: Based on the IR data
*2: With assumption of the strem-lined car-body

3-6 Speed vs. Distance Curve of Trains on the New Corridor (Powering)



3-7 Speed vs. Distance Curve of Trains on the New Corridor (Braking)



3-8 Bolsterless Type Bogie

The bolsterless type bogie is so designed to improve running stability and riding comfort for the high speed rolling stock, and to reduce track destruction and vibration noise for its light weight, and requires less power cost.

(1) Outline

1) In order to reduce track destruction and improve the running stability during the high speed drive, the air spring is directly mounted on the bogie frame instead of the conventional mounting method using the bolster and bolster anchor. The traction device is mounted at the rolling stock body which connects it with the bogie. Furthermore, the bolsterless type bogie has the following features in order to minimize the non-suspended weight.

   a) One-wear wheel
   b) Hollow axle
   c) Flanged cylindrical roller bearing as the journal bearing which reduces the overall length of the axle
   d) Grease lubrication for axle bearing
   e) Gear box and axle box made of aluminum alloy
   f) Speed generator mounted in the suspended part

   In order to minimize the suspended weight, the following systems are adapted which reduce the weight of bogie frame.

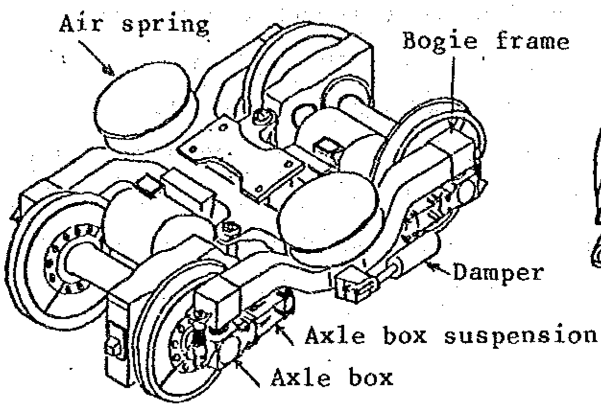
   a) To change the position of the brake cylinder to scrap the end beam
   b) To adapt the new system of axle box suspension to reduce the length of side beam

2) For the rolling of bogie, the damper to add resistance is modified to minimize the snaking motion and the lateral force at a sharp curve, which reduces the wear of the wheel flange and improves riding comfort during high speed drive.

3) The air spring is modified to improve the running stability, curving performance and riding comfort.

4) The wheel tread shape modified, and appropriate support rigidity of axle box is applied to reduce the lateral force and improve the running stability.

Fig. 1 shows an example of bolsterless type bogie and Fig. 2 shows the hollow axle.



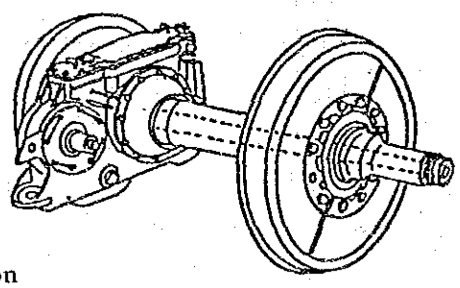


Fig. 1 An Example of Bolsterless Type Bogie

Fig. 2 Hollow Axle

3-9 'WN' Type Coupling

(1) Function

The 'WN' type coupling couples the armature shaft of traction motor in the suspended part and the pinion shaft of gear box in the non-suspended part, and transmits power allowing their relative motion.

The 'WN' type coupling has enough degree of freedom for the displacement of both shafts caused by the variation of deflection of bogie axle spring, and the lateral and longitudinal motion of wheel set.

There are new and old types of couplings. In the new type, the rubber stopper system is adapted in which the air cushion is used instead of the coil spring to prevent the vibration in the axial direction and the coil spring failure.

Figs. 1 and 2 show the driving device and sectional view of coupling respectively.

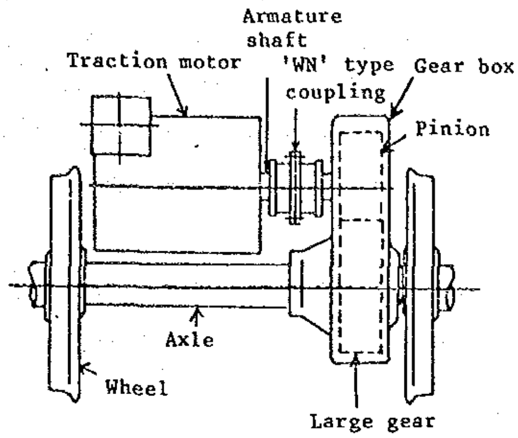


Fig. 1 Driving Device

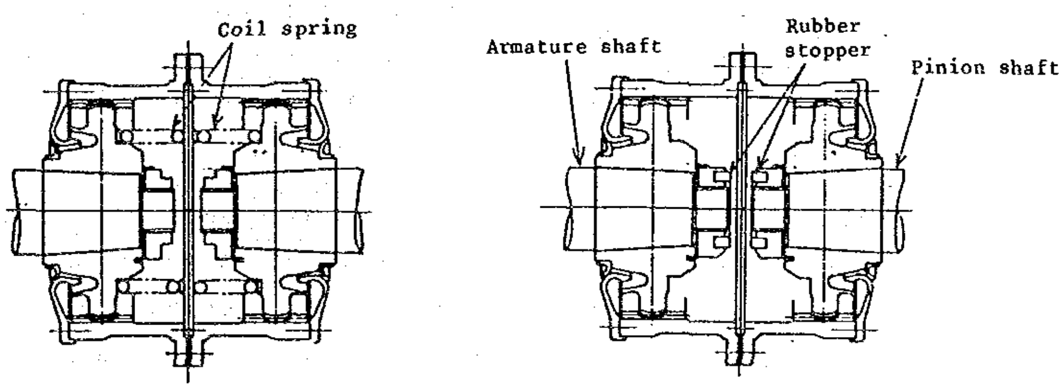


Fig. 2 Sectional View of Coupling

(2) Structure

1) The 'WN' type coupling, the double internal external gear type coupling, has the external gears shrinkage fitted with the tapered part at the end of traction motor armature shaft and pinion shaft, together with the sleeve with the internal teeth of the same number, and the flange on the sleeve tightened by the reamer bolt.

2) The external gear has round teeth end for large crowning, and the internal gear has the large face width to allow the displacement.

3) The sleeve joint has the center plate. In the old type coupling, the function of gear is ensured by pressing both ends of the center plate (which has a hole at the center) with the coil spring, while in the new type, the rubber stopper with the nut presses the center plate (which has no hole at the center) for displacement.

4) For easy assembling and disassembling of traction motor and gear box, 2 pcs. of center plate are mounted.

3-10 Electromagnetic Air Brake

In the conventional automatic air brake, the brake valve controls the pressure reducing and pressure intensification in the brake pipe, and with that brake, the brake is applied in the order from the top to the end of train. For this reason, long idle running time is required to have the effective brake power if the train is long, and the train cannot stop with short brake distance.

For highly responsive brake control, therefore, the magnet valve is mounted in each rolling stock. With this electromagnetic air brake, each magnet valve (Fig. 1) simultaneously operates at cab brake operation, enabling the synchronous brake application and taking off throughout the train.

Fig. 1 shows the schematic diagram of electromagnetic air brake system.

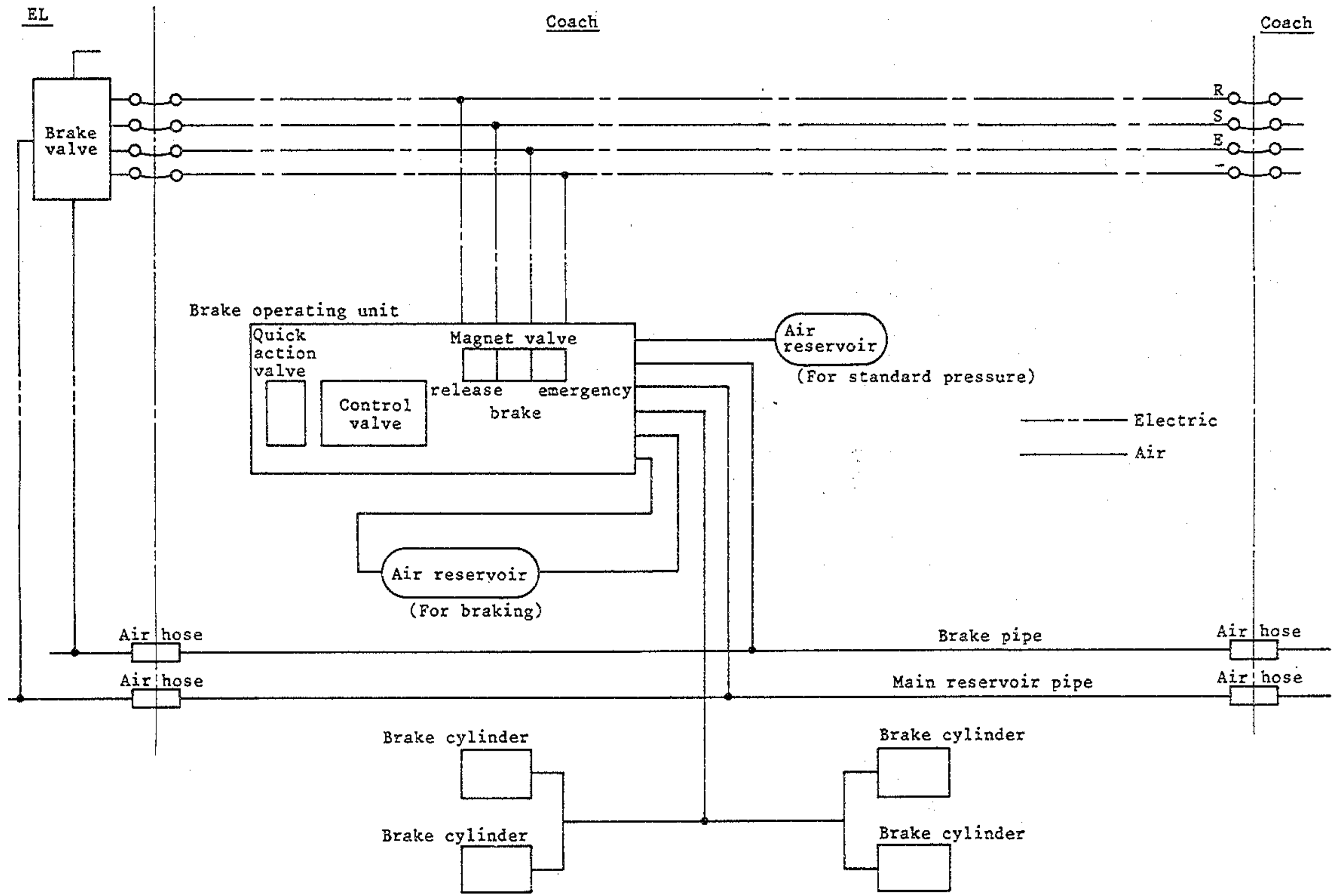


Fig. 1 An Example of Schematic Diagram of Electromagnetic Air Brake System

3-11 Disc Brake

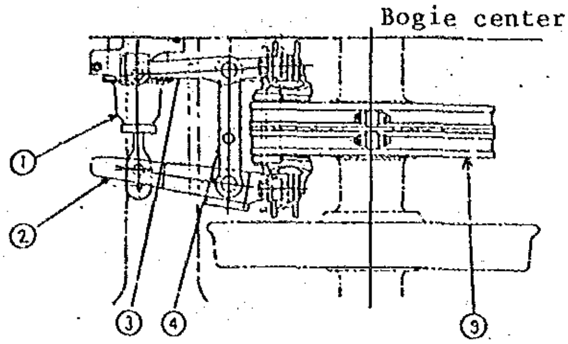
The disc brake system has the axle disc type as shown in Fig. 1 and the wheel disc type as shown in Fig. 2.

The brake power of the disc brake is obtained by pressing the brake disc mounted in the axle or on the wheel onto the lining, it is being widely used as the friction brake for rolling stock and the wheel tread brake.

It features the large absorbing energy and is used for the air brake of high speed train with large brake load, or for eddy current brake of the trailer.

The air or hydraulic power is used for brake cylinder. The brake disc is mounted in the driving truck, which has the traction motor and gear box, at both sides of wheel (wheel disc type), and, in the trailer, between the left and right wheels (axle disc type).

The high speed train with disc brake has the wheel tread cleaner for stable coefficient of friction between rail and wheels.



No.	Name
①	Brake cylinder
②	Brake lever
③	Brake lever
④	Brake lever connection
⑤	Brake lining bracket
⑥	Brake lining hanger
⑦	Brake head
⑧	Lining
⑨	Brake disc

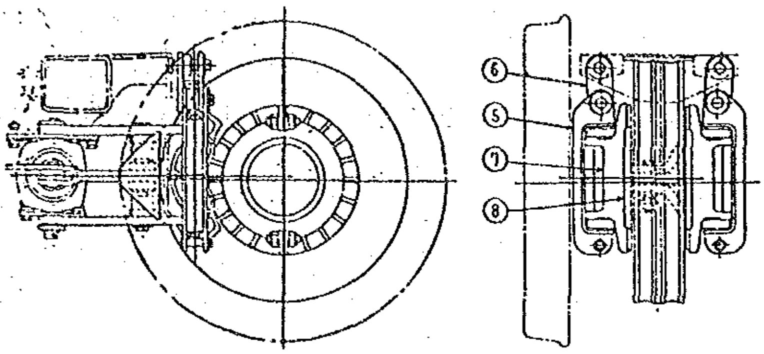
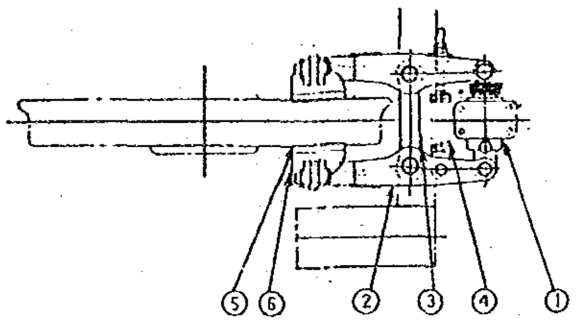


Fig. 1 Axle Disc Type

No.	Name
①	Hydraulic cylinder
②	Brake lever
③	Brake lever connection
④	Release spring
⑤	Lining
⑥	Brake head
⑦	Brake lining hanger
⑧	Brake disc



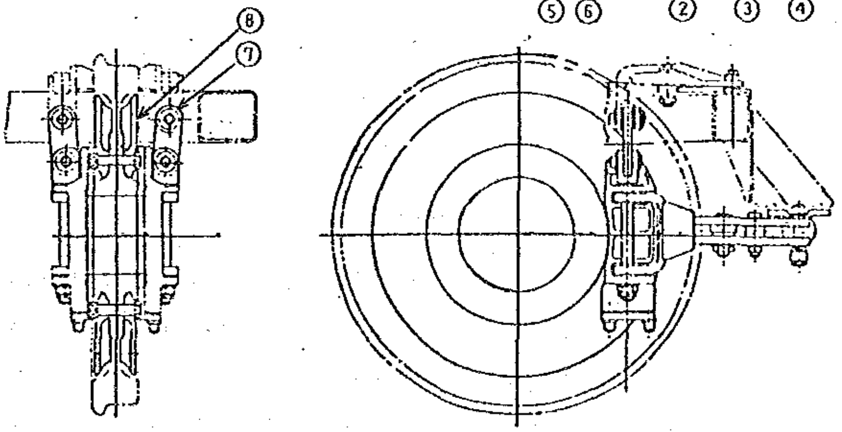


Fig. 2 Wheel Disc Type

3-12 3-phase Asynchronous Motor and Regenerative Brake

(1) General

In improvement in speed of rolling stock, making its weight lighter is desired to avoid raising track maintenance cost. However, the weight of rolling stock tends to increase because of the requirement for increased capacity of individual units of power equipment.

As one way of keeping the weight of rolling stock light while increasing the capacity of power equipment, the DC motor is replaced with an induction motor and the rheostatic brake with a regenerative brake. This allows the traction motor and the main transformer to be light and the main resistor and main controller eliminated. Although an inverter, must be additionally used, the power plant section which accounts for about one fourth of the total weight of a rolling stock can be reduced by about one third.

(2) Problems with brushes and commutator

The following problems are associated with the use of brushes and the commutator which are required for a DC motor.

1) Necessity of regular inspection

Regular inspection including replacement of worn brushes, check of commutator condition, check for contact of commutator and its repair, are required.

2) Failure-causing factors

Failures of DC motors are mostly improper commutation and flashover. In addition, failures of the traction motor plays a major part in rolling stock troubles.

3) Difficulty in increasing the capacity of the traction motor

Because the commutator and brushes occupy a relatively large area, the capacity per unit volume of the traction motor cannot be increased as desired. Consequently, it is difficult to enlarge the output of the traction motor which is to be accommodated in a small space of bogie.

4) Structural weakness

The commutator consists of mica and copper layers laid upon and tightly fastened to one another, resulting in a structural weakness.

(3) The use of induction motor

The induction motor provides a required speed characteristic curve by controlling the interlinkage flux of the rotor and rotor current. However, since, it is difficult to directly detect these two components, it is necessary to calculate and control the frequency, voltage, and slip frequency to be applied to the induction motor based on such parameters as circuit constant, rpm, direction of revolution, current of different phases, etc. Introduction of state-of-the-art power electronics technology with GTO (gate turn-off thyristor) and a microcomputer makes it easier to control frequency and complicated and quick operation of various parameters, which made practical application of the induction motor possible. Because a greater torque is required for the induction motor used as a traction motor, it is necessary to generate a 3-phase current using an inverter. The following improvements are made by utilizing the induction motor.

1) The problem described in (2) is solved by using the induction motor as a traction motor, which does not need any brushes or commutator. This lowers the maintenance cost while enhancing reliability and capacity without increasing the weight of rolling stock.

2) Because torque is abruptly decreased with increase in revolution speed, the re-adhesion performance at the time of slippage of wheels is improved.

3) The induction motor provides the simplest structure of AC motors as well as strength withstanding a higher revolution speed.

4) The capacity of the main transformer can be reduced by controlling and improving power-factor by GTOs.

(4) The use of regenerative brake

The 3-phase asynchronous motor system does not require a main resistor and resistors for brakes because the powering circuit is used as a regenerative brake as it is. This system has advantages in weight, maintenance, and power-factor over the existing rheostatic brake system and regenerative brake system by DC motor.

(5) Others

The problems with the 3-phase asynchronous motor system to be solved in the future include lowing the cost of GTOs, establishing design standard, and enhancing the reliability of the bearings for a high speed motor.

Shown below are the block diagram of the traction circuit by 3-phase asynchronous motor and the standard speed characteristic curve for an induction motor.

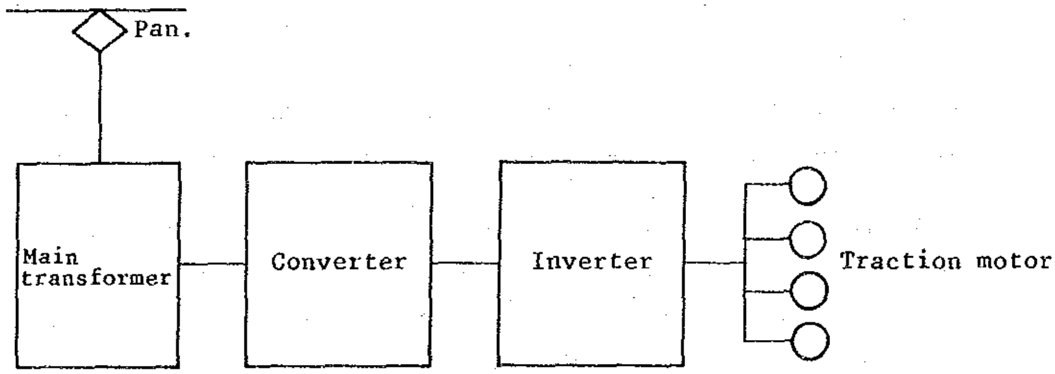
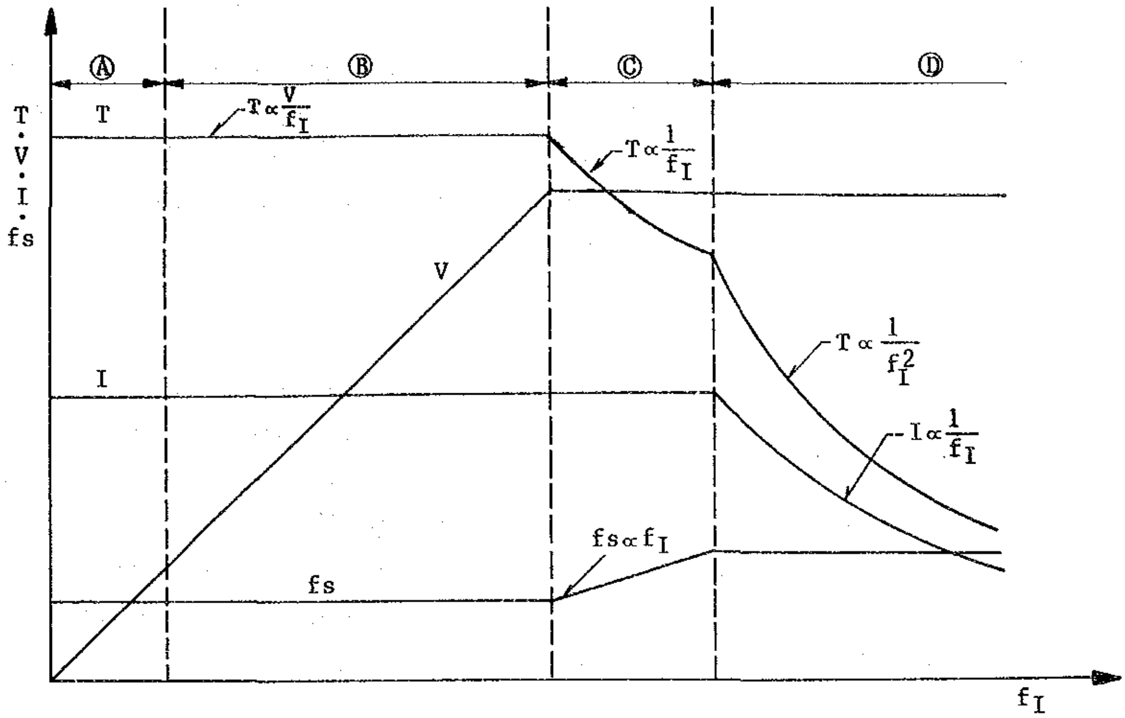


Fig. 1 Block Diagram of Traction Circuit by 3-phase Asynchronous Motor



Ⓐ : Starting region

Ⓑ : Constant-torque region

Ⓒ : Constant-power region

Ⓓ : Characteristic region

T : Torque

V : Invertor output voltage

I : Motor current

f_s: Slip frequency

f_I: Invertor frequency

$$T = K \cdot \left(\frac{V}{f_I}\right)^2 \cdot f_s \qquad T = K' \cdot \frac{V}{f_I} \cdot I$$

$$n = \frac{120}{P}(f_I - f_s)$$

n : Revolutions

P : No. of poles

K, K': Constant

Fig. 2 Standard Speed Characteristic Curve for an Induction Motor

3-13 Eddy Current Brake (ECB brake)

As for the trailer brake system, the rheostatic brake cannot be used, and the air brake application during high speed drive causes the large brake disc and lining abrasion, increasing the maintenance cost. Therefore, in the series 100 Shinkansen EMU, the eddy current brake is used instead of the rheostatic brake in the electric motor coach.

(1) Principle and conception

1) The coils of the same of different pole are mounted on the opposite side on the axle disc. When the current flows to the coils, the disc has the eddy current, and the braking force is obtained by the operation in the magnetic field. Figs. 1 through 4 show the chart of principle, external view, the brake characteristics of each pair of poles, and the characteristics of speed and braking force according to the coil current variation, respectively.

2) The heat energy generated during the brake application causes the temperature rise in the disc and wheel. The material with high heat resistance and good magnetic characteristics has to be used to keep the axle temperature surge within the tempering temperature.

3) For long brake disc and lining life, it is desirable to apply the eddy current brake up to the low speed area as much as possible. Therefore, the mono-pole opposition system which ensures the braking force for up to 70 km/h speed is used. (See Fig. 3 Brake Characteristics for each Pole Opposition.)

Table 1 shows the brake application system of trailer for each speed.

Table 1 Braking System of Trailer
(An example of series 100 Shinkansen EMU)

Speed range	System
230 ∿ 70 km/h	Eddy current brake
70 ∿ 25 km/h	Eddy current brake (required braking force by the rheostatic brake in electric motor coach)
25 km/h or less	Air brake

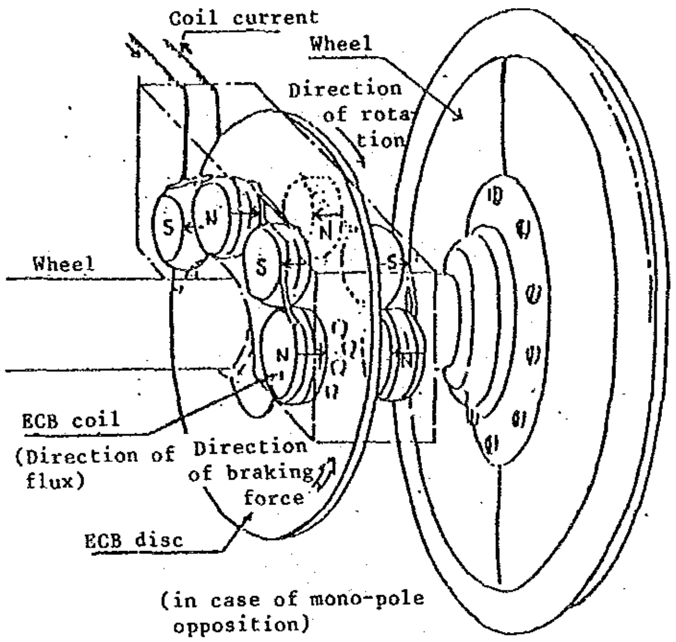
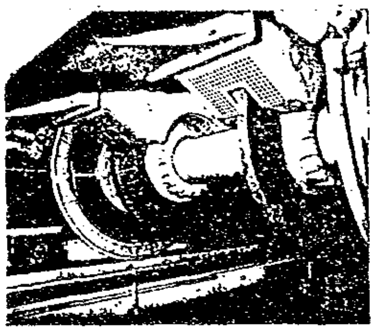


Fig. 1 Chart of Principle Drawing



Eddy-current brakes
The eddy-current brake used for the trailers consists of a wheel disc held between coils to generate an electromagnetic braking force.

Fig. 2 External View

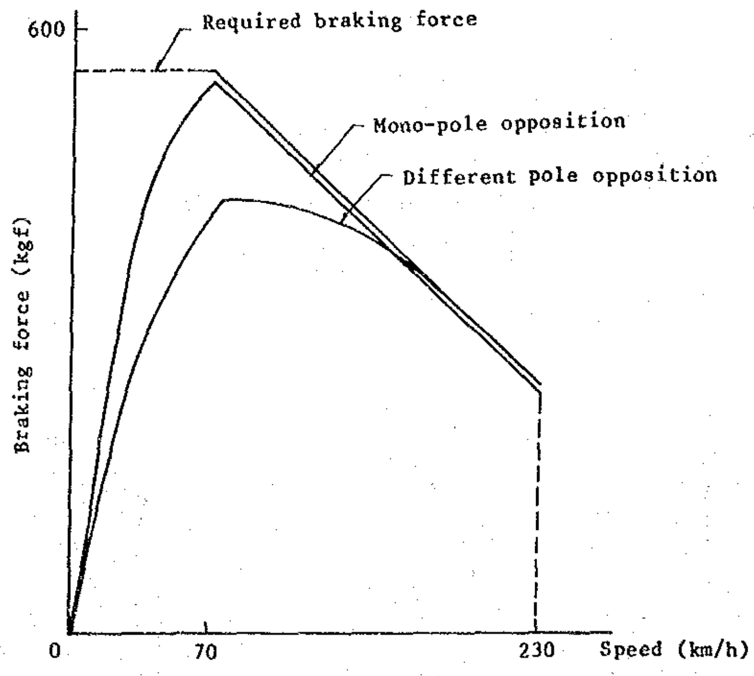


Fig. 3 Brake Characteristics for each Pole Opposition (An example of series 100 Shinkansen)

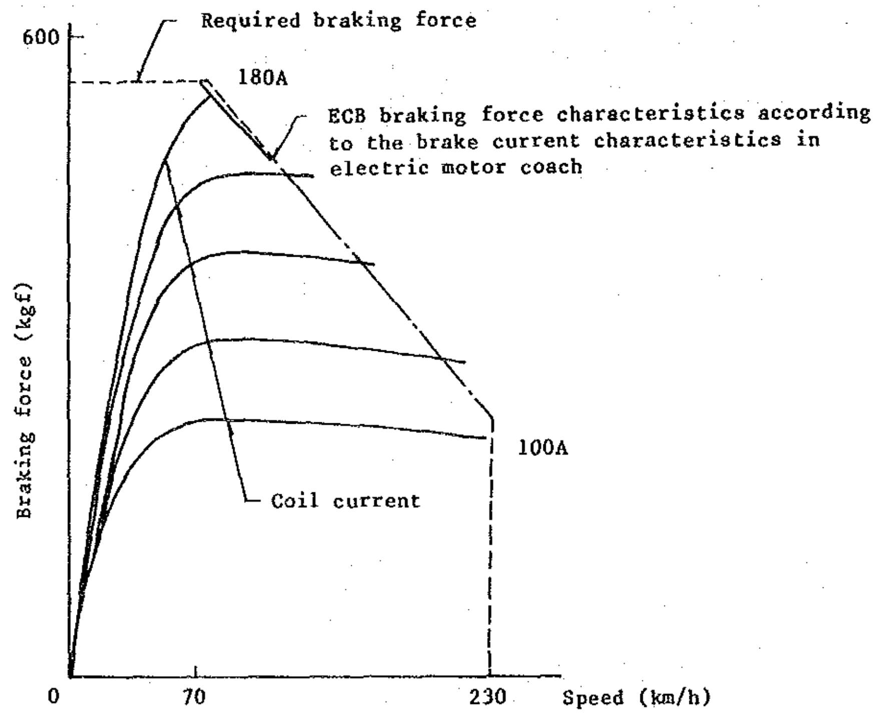


Fig. 4 Speed and Braking Force Characteristics (An example of series 100 Shinkansen)