THE UNITED MEXICAN STATES
PRE-FEASIBILITY REPORT ON MEXICO CITY SUBURBAN RAILWAYS CONSTRUCTION PROJECT

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FEBRUARY 1978

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

With the concurrence of the Government of the United Mexican States, the Government of Japan had decided to conduct a Pre-feasibility study for the Mexico City Suburban Railways Construction Project, and the study was carried out by the Japan International Cooperation Agency (JICA).

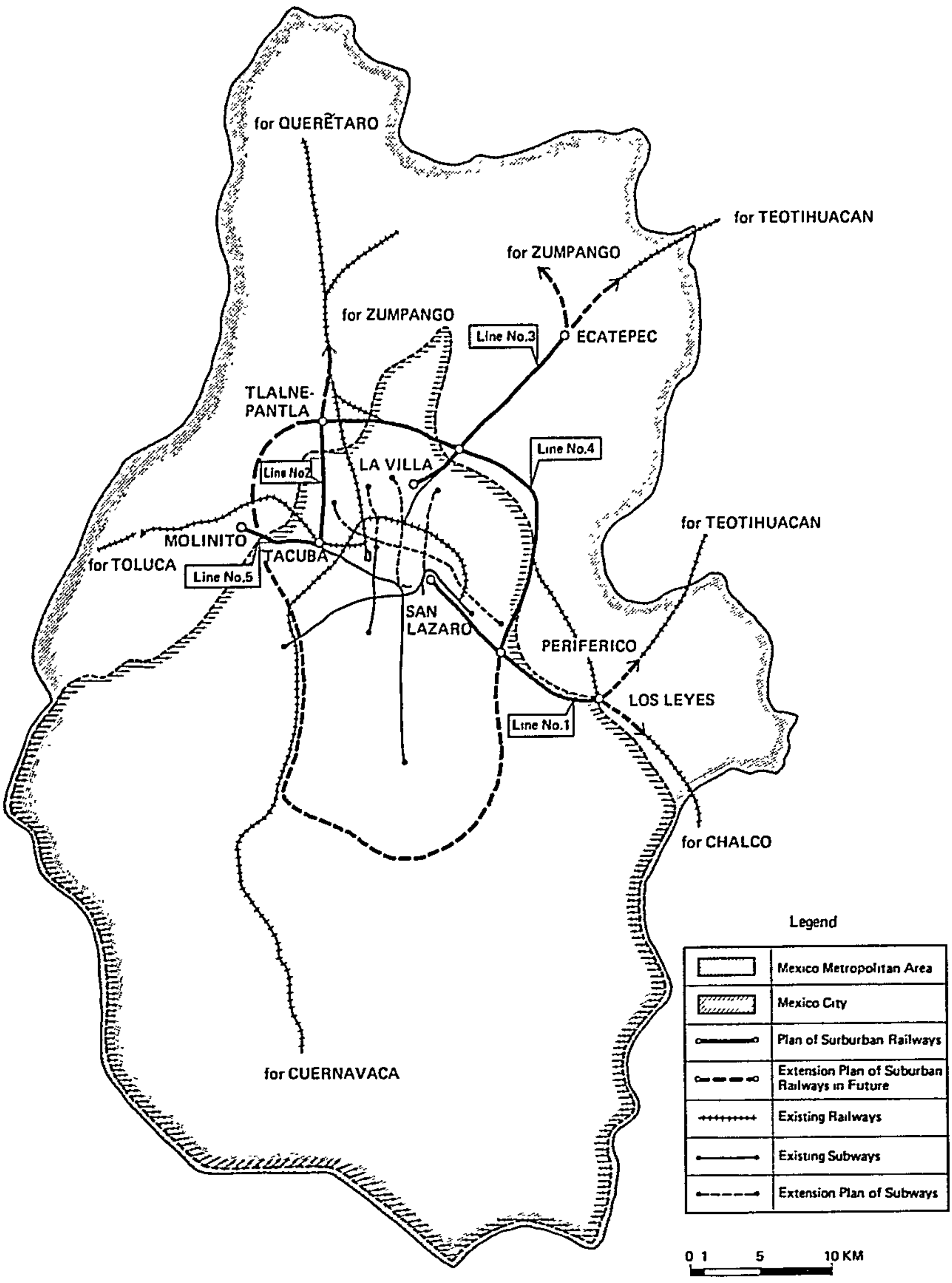
In view of the importance of the project, JICA undertook the study commencing with preliminary study in July 1977, followed by the pre-feasibility study in September 1977. The JICA study team held discussions with officials concerned of the United Mexican States Government on the draft final report which had been submitted in January 1978. The report has now been finalized for submission herewith to the Government of the United Mexican States.

I hope that the present study will serve to expedite the implementation of the project, and contribute to strengthen friendly relations between United Mexican States and Japan.

I would like to take this oppotunity to express my heartfelt gratitude to all the people who participated in this study and to all the Mexican authorities concerned for their cooperation.

February 1978

Shinsaku HOGEN
President
Japan International Cooperation Agency
Tokyo, Japan



Plan of Suburban Railways in Mexico Metropolitan Area

THE JAPANESE SURVEY TEAM
FOR
MEXICO CITY SUBURBAN RAILWAYS CONSTRUCTION PROJECT
IN THE UNITED MEXICAN STATES

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I. Introduction

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1. The Background of the Present Project and the Objective and Scope of the Survey

1-1. The Background of the Project

The United Mexican States has a population of 66 millions, 20% of which, that is, 13 million population is centralized in the Mexico Metropolitan area. The Metropolitan area is gaining population at the annual rate of 6.2%, resulting in the enlargement of the urban area and a rapid growth in population at its environs. If this rate of growth continues, the population will exceed 25 millions in the year of 2000 a.d.

The urban transportation of the present 13 million people now depends largely on the bus services, with private automobiles and taxi cabs being made good use of. As a means of mass transportation they have a subway system covering some 37 km at the center of the city, of which the market share, however, is very low. If the dependency on the on-road transport is continued, with the railway system left unimproved, the public nuissance by air pollution will be worsened still.

With such background the Government of Mexico has the intention to improve the urban transportation by the construction of suburban railway and the extension of the subway system.

1-2. The Objective and Scope of Survey

The present survey has for its object the review of the fundamental plan and the prefeasibility survey of the construction plan, from a technical and economic point of view, on the subject of the suburban railway construction project now planned by the Mexican Government, as a part of reform measures for traffic problems that the Mexico City is now confronted with.

The subject of the survey is the following five railway lines covering some 77 km:

Line No. 1	San Lazaro - Los Reyes	17.0 km
Line No. 2	Tacuba - Tlalnepantla	8.5 km
Line No. 3	La Villa - Ecatepec	18.7 km
Line No. 4	Periferico - Tlalnepantla	27.5 km
Line No. 5	Tacuba - Molinito	5.0 km

The principal tasks performed to achieve the purposes are as follows:

(1) Survey and analysis on the present situation of the city

Survey and analysis on the population, urban facilities, land utilization plan etc., of the Mexico Metropolitan area.

(2) Survey and analysis on the present situation of the traffic

Survey and analysis on the means of transportation, transport facilities and state of their utilization by passengers, in the Mexico Metropolitan area.

(3) Forecast of demands for railway

Collection of information needed for the forecast, and the forecast of the demands.

(4) Review on engineering features

Review on the project plan including alternative plan from the standpoint of construction, and maintenance and operation.

(5) Revenue and expenditure forecast and financial analysis

Revenue and expenditure forecast and financial analysis on a basis of passenger fares, number of railway users, approximate construction cost, operational expenses.

1-3. Outline of Itinerary of Survey Team

Wed.,	21	Sept.,	1977	Survey team arrived in Mexico City.
Thu.,	22	"	"	Visited Japanese Embassy in Mexico.
Fri.,	23	"	"	Visited Ministry of Public Works, Ministry of Telecommunication and Transport, National Railways.
Sat.,	24	"	"	Site survey of planned route of Suburban Railway.
Mon., - Fri.,	26 - 30	"	"	Discussion, in six subcommittees, with specialists of Mexico.
Mon.,	3	Oct.,	"	Visit Subway (workshop, car depot, station, control room). 1st Joint Dellegates Meeting was held.

Tue.,	4	Oct.,	1977	
- Fri.,	7	"	"	Discussion in subcommittees
Fri.,	7	"	"	Interim report to Japanese Embassy. 2nd Joint Dellegates Meeting was held.
Mon.,	10			
- Fri.,	14	"	"	Discussion in subcommittees.
Fri.,	14	"	"	3rd Joint Dellegates Meeting was held.
Sat.,	15	"	"	Final discussion with Mexican side
Mon.,	17	"	"	Visited Ministry of Foreign Affairs, Ministry of Public Works, Ministry of Telecommunication amd Transport, National Railways. Visit Japanese Embassy to report the outline of the survey results.
Tue.,	18	"	"	Left Mexico City.
Wed.,	19	"	"	Arrived in Japan.

II. Summary and Conclusion

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1. Development of Mexico Metropolitan Area and Necessity for New Transport System

Mexico City Metropolitan Area, with a population of approximately 13 million, is one of the largest urban centers of the world. Furthermore, at the current high rate of growth, its population will, in all likelihood, come to exceed 25 million before the end of this century, even surpassing the present population of nearly 25 million of Tokyo Metropolis Transportation Sphere (i.e., the area within a circle approximately 50 km in radius), the largest population mass in the world today.

Under the circumstances, it has become an exceedingly important and a difficult task to provide smooth and efficient transportation, for commuters especially, in this Metropolitan Area.

Transportation in Mexico City Metropolitan Area, today, depends mostly on motorcars, and for mass transportation, there is a 37 km metro which only accounts for approximately 10% of the urban traffic.

Motorcar traffic congestions have already appeared in various localities, and air pollution by motorcar exhaust gas is becoming a serious hazard to city life. It is quite evident, therefore, that strengthening of road transportation alone will not suffice in meeting the rapidly expanding traffic volume induced by population growth, making it all the more urgent to construct new suburban railways and expand the metro system.

2. A Plan of Suburban Railways

Of the approximately 320 km of new suburban railway contemplated by the Government of Mexico, the following 5 lines, totalling 77 km, for the present, being considered.

Line-1	San Lazaro	——	Los Reyes	17.0 km
Line-2	Tacuba	——	Tlalnepantla	8.5 km
Line-3	La Villa	——	Ecatepec	18.7 km
Line-4	Periferico	——	Tlalnepantla	27.5 km

Line-5	Tacuba	- Molinito	5.0 km

Note: For Line-5, the route has not yet been finalized.

In May 1977, the Government of Mexico intimated to the interested countries the outline of the plan for construction of the suburban railway, the main points of which are given in the following.

Outline of Plan for
Construction of Mexico City Suburban Railway

Gauge:	1,435 mm
Track, type:	Double
Gradient, maximum:	3%
Curvature, maximum:	G=3°=R=382 m
Crossing with roads:	Grade-separated
Stations, No. required (phase I, 72 km):	
Transfer stations	3
Terminal stations	6
Intermediate stations	33
Trolley wire voltage:	60 Hz, single-phase AC, 25 kV
Train consist:	6 to 9 cars (12 in future) (using permanently coupled 3-car units of 2 motored cars and 1 trailer)
Speed, maximum:	110 km/h
Scheduled speed:	60 km/h
Acceleration, normal:	1 m/sec^2
Deceleration, normal:	1 m/sec^2
emergency:	1.3 m/sec^2
Car size, length between coupler faces:	25 m
width:	3.3 m
Train operation system:	A.T.P. and A.T.O. systems C.T.C. system at control center
Ticket issuing and examining:	Automatic ticket vending and examining
Headway, minimum:	90 sec
Train stopping time, at intermediate station, average:	15 sec
at transfer station:	25 sec

The plan reveals that by adoption of large-size cars, 25 m in length and 3.3 m in width, and provision of frequent service, eventually with 12-car trains, it is aimed to bring forth a suburban railway system of very high capacity, hardly to be matched elsewhere in the world. Another objective is the attainment of high-speed operation by adopting a relatively large spacing of 2.5 km, in average, between stations and high-performance cars excelling in speed, acceleration and deceleration characteristics.

It is further noted that the most up-to-date technology is to be incorporated, such as on AC electrification, A.T.P. and A.T.O., aluminum body vehicle, and automatic ticket vending and examining.

These targets sought for in the plan are deemed most appropriate for a suburban railway serving such a mammoth urban area as Mexico City, and upon completion of the projected undertaking, it is certain that a system with the highest capacity and technology in the world will become a reality. From a farsighted viewpoint especially, this will undoubtedly become the most effective railway in the world.

In drafting this construction plan, the Mexican authorities requested this Survey Team to set forth alternatives whenever relevant to allow room for selection, instead of focusing only on the optimum. Accordingly, in taking up each field, alternatives have been given whenever there is room for choice, designating the more costly one as "Alternative-A" and the less costly one as "Alternative-B", and the total construction cost was likewise distinguished into A and B, each being the sum total of the costs falling under either one of the categories. The most feasible final plan, therefore, could most likely be a combination of Alternative-A and Alternative-B, following their selection in each field, with the total construction cost lying somewhere between the Alternative-A and Alternative-B totals.

3. Estimate of Traffic Demand

Estimation of future traffic demand is a prerequisite to railway construction planning. An estimation was made of the number of passengers boarding at each station, total number of passengers boarding on each line, number of passengers passing on each line, etc., based, in the first instance, on the

26-zone OD (Origin and Destination) table of the 1976 survey, demographic study of 180 zones of Mexico City Area, past surveys on the traffic volume of each mode of transportation, etc., and then, by applying the various formulas, etc. of COPLINTRA. Furthermore, from the rate of population growth along each line, an estimation was made of the anticipated passenger traffic growth. The results of the above are shown in the following tables and figure.

Table II-3-1. Estimated Number of Passengers Boarding by Line

Line / Year	Line-1	Line-2	Line-3	Line-4	Line-5	Total
1982	237,465	107,540	91,370	89,891	63,325	589,591
1985	368,222	170,273	140,435	144,646	99,912	923,488
1990	447,286	197,950	159,189	183,131	117,539	1,105,095
1995	524,413	227,468	178,707	219,508	136,944	1,287,040

Notes: 1. Figures denote annual totals in thousands.

2. Days of the week have been taken as follows:

Ordinary weekdays	-	240 days
Sundays and holidays	-	73 days
Saturdays	-	52 days
Total	-	365 days

3. Fluctuation by day of the week

Ordinary weekdays	100%
Sundays and holidays	73%
Saturdays	87%

4. Figures for transfer stations on each line have been treated as follows:

Periferico	included	in	Line-1
Xalostoc	"	"	Line-3
Tlalnepantla	"	"	Line-2
Tacuba	"	"	Line-2

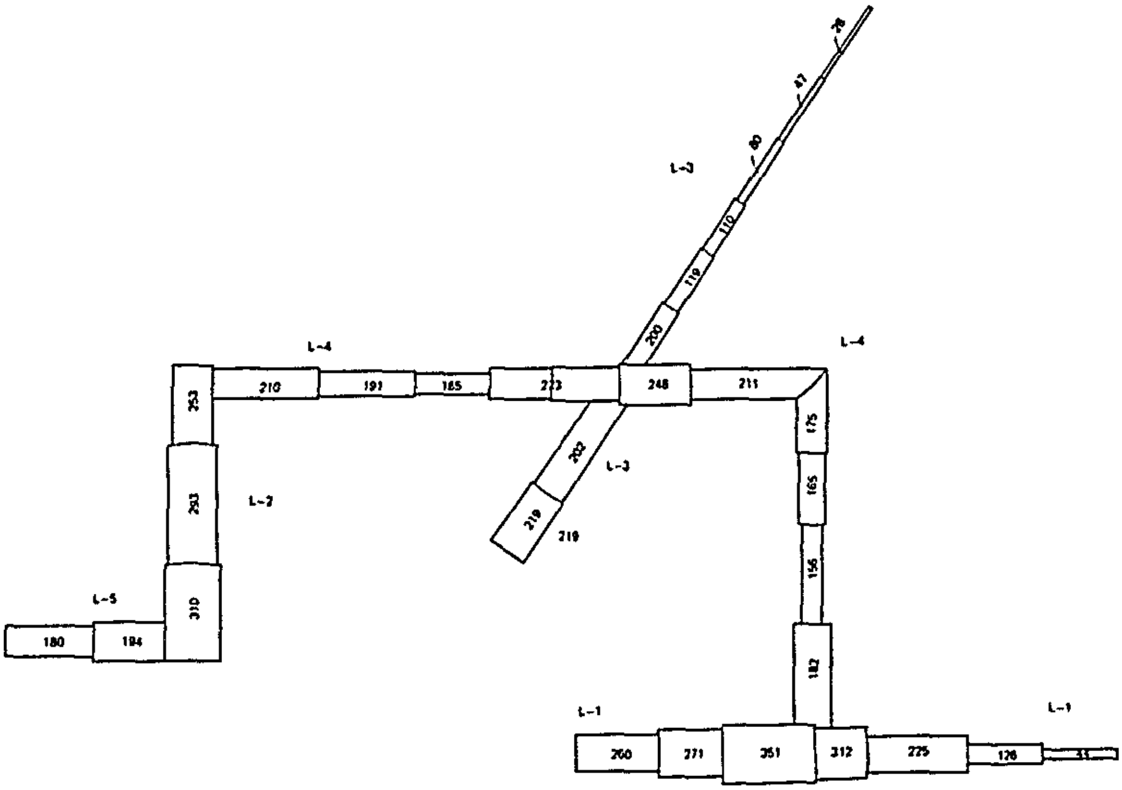


Fig. II-3-1. Number of Passengers (1982)
(in thousands per day, two way)

Table II-3-2. Traffic Volume Per Day, Two Way, by Line and Year

Unit: Passenger

Line	Densest section	1982	1985	1990	1995
Line 1	Periferico - Telecomunicationes	350, 523 (100)	543, 536 (155)	660, 240 (188)	774, 089 (221)
Line 3	La Villa - Carrera	219, 020 (100)	336, 631 (154)	381, 585 (172)	428, 369 (196)
Line 4	San Felipe - Xalostoc	247, 821 (100)	398, 783 (161)	504, 878 (204)	605, 168 (244)
Line 2 & Line 5	Tacuba - Atzcapozalco	310, 488 (100)	491, 606 (158)	571, 511 (184)	656, 743 (211)

Note: Figures in parentheses indicate indices with 1982 as 100.

Next, it is necessary to determine the peak one hour traffic volume from the whole day traffic volume. By using the COPLINTRA formula, the rate of passenger concentration in the peak hour, that is, the proportion of the average peak hour traffic volume to the whole day one way traffic volume, was determined to be 21%. On the other hand, according to the Person Trip Survey for Mexico City Area, the rate of concentration was found to be 17%. It was decided, therefore, to use both values by setting the upper limit value at 21% (Alternative-A), and the lower limit value at 17% (Alternative-B), and formulate train operation plans based on these two alternatives.

4. Train Operation Plan

As mentioned before, the peak one hour traffic volume was determined from the whole day traffic volume on the heaviest traffic section of each line for selected years, based on the demand estimation, and from the results, the appropriate train consist and the number of trains to be operated per hour were determined. Following this, the train diagram was drawn up for each line and the number of cars required was determined. As stated before, it is to be noted that the values of Alternative-A and Alternative-B were based on peak hour traffic concentration values of 21% and 17%, respectively.

The results of the above are shown in the following tables,

Table II-4-1. Initial Headway and Train Consist

Line	Headway during rush hour		Train consist	
	Alternative-A	Alternative-B	Alternative-A	Alternative-B
Line-1	5 min	4 min	9 cars	6 cars
Line-3	5 min	6 min	6 cars	6 cars
Line-4	4 min 40 sec	6 min	6 cars	6 cars
Line-2 and Line-5	3 min 45 sec	4 min 40 sec	6 cars	6 cars

Table II-4-2. Time Required

Line	Section	Distance (km)	Time-required (min-sec)	Scheduled speed (km/h)	Average speed (km/h)
Line-1	San Lazaro - Los Reyes	16.9	19-30	52.0	57.4
Line-3	La Villa - Ecatepec	18.9	22-30	50.4	57.7
Line-4	Periferico - Tlalnepantla	27.7	30-00	55.4	62.7
Line-2 and Line-5	Tlalnepantla - Molinito	13.2	15-30	51.1	59.0

Table II-4-3. Number of Cars Required (Alternative-A)

Year / Line	1982	1985	1990	1995
L1	105	153	174	213
L3	78	114	120	141
L4	108	162	198	240
L2&L5	78	123	129	150
Total	369	552	621	744

Table II-4-4. Number of Cars Required (Alternative-B)

Year / Line	1982	1985	1990	1995
L1	90	135	159	174
L3	72	90	102	114
L4	84	129	171	198
L2&L5	72	105	111	129
Total	318	459	543	615

As to the requirements for prevention of train accidents and securance of safe operation, it is deemed that adoption of the Automatic Train Control System (A.T.C.) is absolutely essential. It is realized that when the train interval shortens to 2 minutes or less in the future on account of heavier traffic, there will be the need to provide, in addition, the Automatic Train Operation System (A.T.O.), but during the period of less train frequency, A.T.O. could be economized. Therefore, two plans have been set forth, Alternative-A with A.T.C. and A.T.O. and Alternative-B with only A.T.C.

Whilst the addition of A.T.O. would raise the initial construction cost, it would have the advantage of simplifying the training of driver.

5. Railway Facilities

Based on the plan of the Mexican authorities, and taking into account the characteristics of this suburban railway for the exclusive operation of electric multiple-unit trains under a highly dense schedule, and also, the soft ground conditions prevailing in the area, it was determined to adopt structures which would be effective in saving maintenance manpower after their completion.

At the same time, due attention was paid to such other important aspects as reduction of construction cost and motive power cost, and improvement of riding quality, taking into consideration the experience in Japan, and what was deemed most desirable has been set forth with respect to the following:

(1) Construction gauge

(2) Track layout, longitudinal alignment

(3) Structure of roadbed

(4) Structure of grade separation

(5) Structure of track

(6) Maintenance system of track

6. Facilities at Stations

It was requested by the Mexican authorities to take into account their ultimate aim of adopting the 90 second headway, to enable the operation of 3000 m long 12-car trains at a headway under 2 minutes, there will be the need for special track layout, especially at the terminal stations.

According to the plan of the Mexican authorities, platforms for boarding and alighting are to be separated at all stations, with the 3-platform and 2-track system at intermediate stations and the 5-platform and 4-track system at terminal stations. This is quite understandable, but at stations where only a small amount of traffic can be expected for some period after the inauguration of services, it is felt that one platform could suffice for both boarding and alighting. Furthermore, as to the length of the platform, there is the possibility of saving initial capital expenditures by building, first, platforms long enough to accommodate 6-car trains to be operated in the initial period, and later extend it for 9-car or 12-car trains as need arises.

It is under these considerations that two Alternatives, Alternative-A and Alternative-B, have been set forth, the former being the ideal one with separate platforms for boarding and alighting, and the latter, the economic one with platform for boarding and alighting joint use at stations with only a small amount of traffic in the initial period.

Two Alternatives have likewise been set forth for automatic ticket issuing and examining, Alternative-A for issuing of tickets only and Alternative-B for issuing of both tickets and coupons.

7. Electric Power Facilities

It is proposed that traction substations be located at 2 places, with 2 feeding transformers at the one at Xalostoc and 1 at the one at Las Torres.

As to the linkage between the power network of the power company and the substation, it is not yet known whether there will be the need to construct a special power transmission line for the purpose, or whether a branch-off from the nearest point of the power company line will be possible, this depending on future negotiations; so, under the circumstances, the former case has been taken up as Alternative-A and the latter, as Alternative-B.

Since it is desirable to set up the remote control center of the substations at the location of the train control center, it is proposed to place it at San Lazaro.

As to the feeding system, the AT feeding system is recommended. This is because it has the advantage of greater power supply capacity and less voltage drop, compared with the BT feeding system. Besides, the BT feeding system has a weakness in the BT section as regards current collection and maintenance, which all go to make it undesirable for the projected suburban railway.

With respect to the catenary facilities, the designing was done giving due regard to the electric wire material, so that the electrical performance of the facilities will meet operating requirements.

8. Signal and Telecommunication Facilities

It is proposed to adopt Automatic Train Control equipment (A.T.C.) and relay interlocking equipment as a means of securing safety in the mass transportation by the projected suburban railway, and Total Traffic Control equipment (T.T.C.) and train radio equipment for punctual and efficient operation. These fulfill the functions required of A.T.P. and A.T.S. mentioned in the plan of the Mexican authorities. Furthermore, information transmission facilities and others considered beneficial have been taken up to facilitate transportation job performance. The control center is to be located at San Lazaro.

As to inductive disturbance accompanying AC electrification, and the countermeasures therefor, an approximate calculation was made taking into account the experience in Japan, and the Alternative incorporating the maximum countermeasures for each of the aforementioned facilities, and hence the costly one, has been termed Alternative-A, and the one with the minimum countermeasures, that is, the less costly one, has been designated as Alternative-B.

In this connection, it is to be noted that the wayside devices required for Automatic Train Operation (A.T.O.) have been included in Alternative-A.

9. Vehicles

The rolling stock gauge, car unit, type of cars, facilities and equipment for each type of car, capacity of each equipment, carbody material, seating arrangement, type of bogie, control system, brake system, etc. were studied in detail and determined, based on the plan of the Mexican authorities.

As to the main features of the cars proposed, the 3-car unit, consisting of 2 motored cars and 1 trailer car in an MM'T formation, is to be used in multiples to make up trains of 6 cars, 9 cars or 12 cars; and the output of the main motor has been set at 180 kw to meet the operating requirements under the plan of the Mexican authorities. The car is to be 25 m in length and 3.3 m in width, with 4 doors on each side, and with bench-type seats lengthwise, and cross-seats in the four corners for the elderly and children, so as to be adapted to mass transportation.

For the carbody material, both aluminum and steel have been considered. The use of aluminum has the disadvantage of raising the car production cost by about 5%, and because of the new technique involved, immediate production of aluminum cars in Mexico may not be possible. On the other hand, it has the advantage of reducing car weight and power consumption, compared with steel, and besides, its durability is greater than steel and it simplifies painting.

Mention was made, under II-4 Train Operation Plan, of the possibility of using both A.T.C. and A.T.O. (Alternative-A), and only A.T.C. (Alternative-B). In this connection, it should be noted that the main equipment for A.T.O. is to be installed on the car, and hence, the difference in the cost of the two Alternatives is seen mainly as the difference in the car production cost, which is approximately 6%.

10. Car Depots and Workshop

In order to determine the size and capacity of car depots and workshop, it will be necessary to decide upon the inspection system to be adopted, in addition to the size of the car fleet mentioned before.

In setting up the inspection system, inspections have been classified into periodic inspection, consisting of general inspection, main component inspection, monthly inspection and daily inspection; and special inspection, taking into account the experience in Japan.

As to the inspection cycle, two systems have been set forth - an interim one to be applied initially for some time after inauguration of services, and another to be applied thereafter.

As to the location of car depots, Los Reyes, Ecatepec and Xalostoc have been selected, taking into account the factors of train sets utilization, size of the depots, and land acquisition.

In determining the size and capacity of the car depots, the extent to which various track groups and main facilities will be required was considered, based on the number of cars to be assigned to each depot up till 1995.

As to the location of the workshop, it was decided that it should be established at only one place, adjacent to the Ecatepec car depot, in order to concentrate and simplify the work and facilitate coordination with the car depots, taking into account the size of the future car fleet.

Further, the flow and scheduling of inspection and repair work, equipment required, general layout, etc. were determined.

11. Construction Plan

11-1. Provisionally Estimated Construction Cost

The construction cost was provisionally estimated based on the following preconditions:

(1) Materials and equipment are to be procured in Mexico as far as possible, with the exception of such items as electrical machinery and apparatus and rail which are to be imported. Besides, in the early stage, all such items as rolling stock and automatic ticket vending and examining machines are to be entirely imported, and thereafter, their domestic production promoted progressively.

(2) All the manpower for technical and manual work required for construction at site are to be secured domestically, with their wages conforming to domestic standards, and their work productivity is to be regarded as being equal to that in Japan.

(3) The price of the materials and equipment to be imported is to be based

on C.I.F. terms applying in 1977, and further, the cost of transportation in Mexico is to be included in the said price.

(4) The per kilometer construction cost of Line-5 is to be regarded as the same as the average for Lines 1 to 4.

(5) The construction cost is to be expressed in peso currency, for which the following exchange rate is to be applied:

1 U.S. dollar = 23 pesos = 250 yen

The initial construction cost, as provisionally estimated based on the above preconditions, is given in the following table.

Table II-11-1. Provisionally Estimated Construction Cost

(in million pesos)

Item	Alternative-A		Alternative-B	
	Remarks	Amount	Remarks	Amount
Civil construction	1) Separate platforms for boarding and alighting 2) Automatic vending and examining of tickets only	9,022 (1,595)	1) Boarding and alighting joint use platform 2) Automating vending and examining of both tickets and coupons	7,821 (1,104)
Electric power	Special power transmission line required	2,221 (891)	Branch-off from nearest line of power company	1,395 (523)
Signal and telecommunication	1) With maximum inductive countermeasures 2) ATC + ATO	1,731 (1,514)	1) With minimum inductive counter measures 2) ATC	1,416 (1,240)
Car depot	In accordance with size of car fleet	1,327 (479)	In accordance with size of car fleet	1,296 (479)
Rolling stock	1) Initial car fleet 369 cars 2) ATC + ATO	6,107 (6,059)	1) Initial car fleet 318 cars 2) ATC	4,952 (4,910)
General management expense		1,691 (-)		1,436 (-)
Total		22,099 (10,538)		18,316 (8,256)

Note: Figures in parentheses represent foreign currency portions of the unparenthesized amounts.

The additional construction cost after inauguration of services is attributable mainly to the expansion in the car fleet made necessary by the growth in traffic volume, as shown in the following table.

Table II-11-2. Additional Construction Cost after Inauguration of Services

(in million Mexican pesos)

Item	1982 - 1986	1987 - 1991	1992 - 1996	Total
Civil construction	418 238	209 175	206 101	833 514
Electric power	46 24	214 149	- -	260 173
Car depot	- -	19 19	19 19	38 38
Rolling stock	2,858 2,146	1,115 1,067	1,695 926	5,668 4,139
General management expense	204 141	90 79	118 64	412 284
Total	3,526 2,549	1,647 1,489	2,038 1,110	7,211 5,148

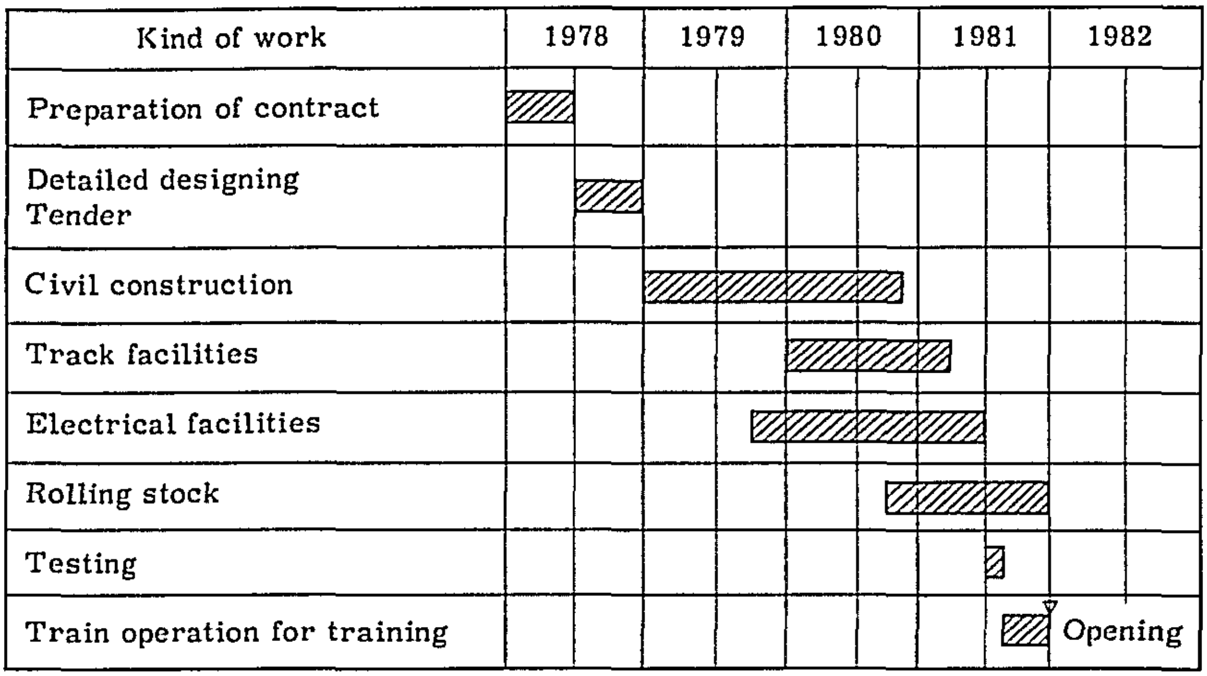
Note: The upper figure in each row denotes the one for Alternative-A and the lower one for Alternative-B.

11-2. Construction Schedule

The construction schedule for simulaneous opening of all the five lines is shown in the following table. In order to complete the project according to schedule, it is important to start the time-consuming grade separation work as early as possible, and conduct the track and electrical work simultaneously during the civil engineering work, to shorten the construction period.

Table II-11-3. Construction Schedule

(for simultaneous opening of all lines)



11-3. Construction Priority of the Five Lines

In determining the construction priority of the five lines, the following conditions are considerable:

(1) To give high priority to the line where there is a shortage of transportation, especially for commuters, causing hardship to the people.

(2) To give high priority to the line most effective in relieving the congestion of the metro.

(3) To give high priority to the line which would enable interline connections for the convenience of passengers as well as for empty movement of car to the workshop for repair.

It is felt that if the Mexican Government would determine the priorities, the following order could very well be arrived at, taking into consideration the conditions mentioned.

1st priority	Line-1 and Line-4
2nd priority	Line-2 and Line-3
3rd priority	Line-5

Nevertheless, in view of the conditions prevailing in Mexico City today, and the high growth anticipated, a suburban railway network of a scale under consideration (i. e., five lines, 77 km) should be completed in any event within

5 years.

12. Estimate of Revenue and Expenses and Financial Analysis

The following has been based on the assumption that all lines will be constructed and opened simultaneously.

12-1. Capital cost

The initial capital cost, being the initial construction cost mentioned before plus the interest expense during construction, amounts to 25 billion pesos under Alternative-A, and 20.7 billion pesos under Alternative-B. The additional capital cost arising after the commencement of operations amounts to 7.2 billion pesos under Alternative-A, and 5.1 billion pesos under Alternative-B.

Initial Capital Cost

(in million pesos and million U.S. dollars)

	Alternative-A	Alternative-B
Initial construction cost	22,099 (10,538)	18,316 (8,256)
(in U.S. dollars)	961 (458)	796 (359)
Interest during construction	2,924 (-)	2,425 (-)
(in U.S. dollars)	127 (-)	105 (-)
Total	25,023 (10,538)	20,741 (8,256)
(in U.S. dollars)	1,088 (458)	902 (359)

Note: Figures in ( ) represent foreign portions

Additional Capital Cost

(in million pesos and million U.S. dollars)

	Alternative-A	Alternative-B
1982 - 1986	3,526	2,549
1987 - 1991	1,647	1,489
1992 - 1996	2,038	1,110
Total (in U.S. dollars)	7,211 (314)	5,148 (224)

12-2. Financing Plan

Funds for the initial capital cost are to be procured entirely in the form of borrowings from external sources, in accordance with the request of the Mexican authorities. For this purpose, a combination of the following three forms of fund raising for the initial capital cost are contemplated.

(1) Export Credit (Suppliers' Credit)

Applicable to: 85% of the foreign currency portion of the material and equipment to be imported, and to the local cost of installing the said material and equipment (this corresponds to 15% of the material and equipment cost imported)

Amount: Alternative-A 10.5 billion pesos (equiv. to 458 million U.S. dollars)

Alternative-B 8.3 billion pesos (equiv. to 359 million U.S. dollars)

Interest rate: Assumed at 7.5% p.a.

Repayment: To be repaid in 20 equal semiannual installments from commencement of operations.

(2) Syndicated Loan

Applicable to: Funds required other than those to be procured under (1) and (3)

Amount: Alternative-A 12.2 billion pesos (equiv. to 530 million U.S. dollars)

Alternative-B 10.2 billion pesos (equiv. to 443 million U.S. dollars)

Interest rate: Assumed at 8.75% p.a.

Repayment: To be repaid in 8 semiannual installments after a grace period of 3 years

(3) Railway Bonds

Amount: for Alternative-A and Alternative-B, both 2.3 billion pesos (equiv. to 100 million U.S. dollars)

Coupon rate: Assumed at 7.5% p.a.

Redemption: To be redeemed in 5 years after a grace period of 5 years

Furthermore, it was assumed that any cash flow deficits after commencement of operations would be made up by the Mexican Government, or other public entities, by interest free loans and that such assistance funds would be repaid from cash surpluses appearing after a favorable balance between revenue and expenses has been achieved.

12-3. Operating Revenue and Expenses

The operating revenue was estimated based on the following conditions:

(1) The annual volume of passenger traffic was based on the aforementioned "III-3 Estimation of Traffic Demand".

(2) For the fare, two levels of 3 pesos and 4 pesos were assumed with the same fixed rate being used for all lines.

(3) It was assumed that the fare level would remain the same for 15 years.

The operating expenses was estimated based on the following conditions:

(1) 1977 price level expressed in pesos
(exchange rate; 1 U.S. dollar = 23 pesos = 250 yen)

(2) In calculating the personnel expense, a uniform pay of 150,480 pesos /year was assumed

(3) The general management expense was estimated to be 10% of the other material expense and 35% of the other personnel expense.

(4) No escalation is assumed for operating expense for a period of 15 years after the commencement of operations.

The effect of rise in prices has been taken up in Case-5.

12-4. Profit and Loss, Cash Flow Projections

Various cases have been considered, depending upon the combination of the capital cost, fare level, etc., but the most standard case is used as the "Base Case".

Case-1 (Base Case)

(1) For the initial capital cost, 20.7 billion pesos under Alternative-B was used, and this amount is to be disbursed in equal annual amounts during the 3 years of the construction period (1979 - 1981).

(2) The cash flow deficits caused by the additional capital cost, operating loss, etc. is to be made up by interest free loans from the Mexican Government or other public entities.

(3) A flat fare of 4 pesos has been adopted.

(4) No allowance has been made for inflation.

In this Case, an operating loss is expected to be incurred in the first 2 years after commencement of operations in 1982, but from the third year, that is 1984, a profit will be realized, which should continue to increase thereafter.

The financial assistance from the Government or other public entities will be required in the amount of 10.7 billion pesos for a 5 year period from the commencement of operations until 1986. Repayment of the assistance is to be fully completed in 1992, the eleventh year after the commencement of business. Thereafter, the surplus funds are to be retained as accumulated cash which, at the end of 1996, will amount to 17 billion pesos.

Case-2

In this Case, Alternative-A has been adopted for initial capital cost (25.0 billion pesos), for additional capital cost (7.2 billion pesos) and also for operating expense. Other conditions are the same as for Case-1.

It will take 4 years, or 1 year more than Case-1, to realize a profit, and further assistance from the Government or other public entities amounting to 16.5 billion pesos will be required for a longer period of 6 years.

Case-3

In the Base Case, that is Case-1, the initial capital cost of 20.7 billion pesos (Alternative-B) includes the amount of 4.6 billion pesos for grade separation. This, however, is a public investment made necessary to avoid level crossings between rail and road, and therefore, from its very nature, it seems to be improper for the railway to bear the whole amount and recover it from fares. Accordingly, in Case-3, this amount has been excluded, reducing the initial capital cost to 16.1 billion pesos, in line with which, the fare was also reduced to 3 pesos. In this case, a profit will be realized in the fourth year, and the assistance from the Government or public entities will be required for 6 years. Although this is the same as Case-2, it is noteworthy that under Case-3, the assistance to be sought from the Government or other public entities will only amount to 9.4 billion pesos, which is substantial reduction compared with Cases 1 and 2.

If the cost of grade separation is to be removed from the fare burden, the project becomes fully feasible at a fare level of 3 pesos.

It might be mentioned further that in many countries state and/or local governments often provide subsidies for the construction of suburban railways and metros in large city areas.

Case-4

Whilst under cases 1 to 3 mentioned before, the shortage of funds was covered by Government or other public entities loans without interest, in Case-4, the income statement and cash flow were determined under the assumption that the loans would bear interest at 8.75% p.a., provided that other conditions would be the same as the base case (Case-1).

In this Case, a profit will be realized in the fourth year, and whilst loans will be required for 6 years as in Case-2 (Alternative-A for capital cost), the total additional loans required would amount to 14.5 billion pesos, which is still 2 billion pesos less than Case-2.

Case-5

In all the foregoing Cases, it was assumed that there would be no change in currency value and that prices and fare levels would also remain unchanged for 15 years. In Case-5, however, the factor of price increases was taken into consideration.

If prices are to rise at the rate of 10% every year, taking 1979 as the base year, the level of prices in 1996 will become 3.8 times the level in 1982, the year of commencement of operations. Even if it is assumed that the capital cost and operating expense would rise at the same rate, this Case shows that the project would still be commercially viable, assuming government financial assistance, by raising the fare 1 peso every 5 years, that is, in 1996 it would be 6 pesos, or an increase of only 50% over 4 pesos.

In other words, this indicates that an enterprise such as the railway, where heavy capital expenditures are made in the early years, tends to be highly resistant to price inflation.

Case 6

This is the result of a tentative calculation based on the assumption that the fare (referred to in Case 1) will be 5 pesos, and shows that the financial burden will be greatly reduced as compared with the other Cases, both in terms of operational revenue and interms of expenditures and cash flow. The project should be in the black in the second year of operation, and the shortage in funds after the opening of services will be limited only to 6,700 million pesos, thus leading to the possibility of complete financial independence of the enterprise as early as 1989.

The main points of these Cases are set out in Table II-12-1, and the prospects of revenue and expense as well as cash flow, in Fig. II-12-1, and Fig. II-12-2.

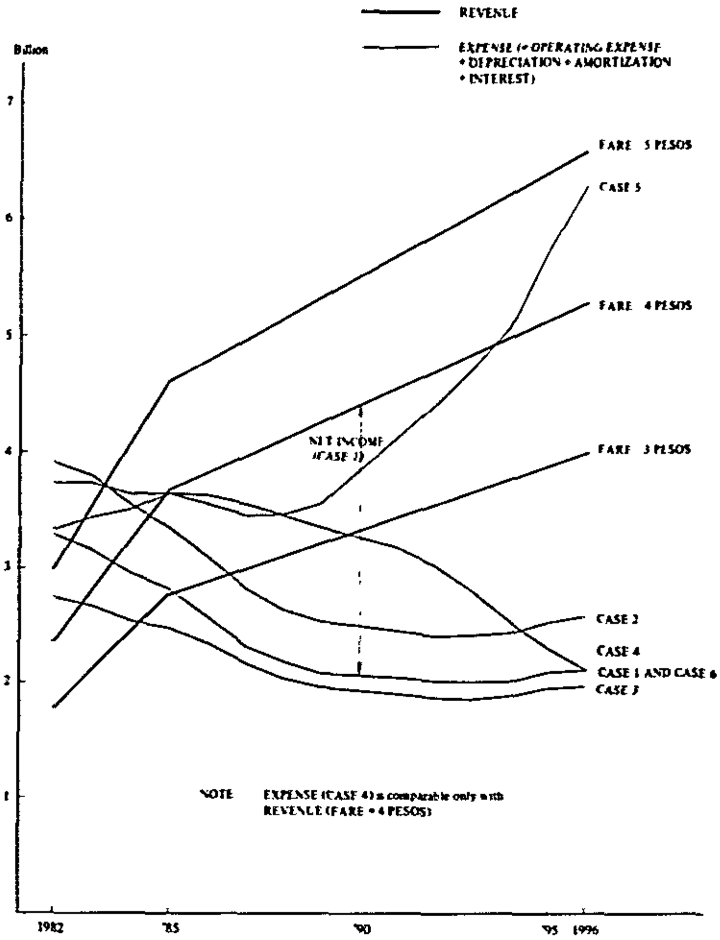


Fig. II-12-1. Revenue and Expense

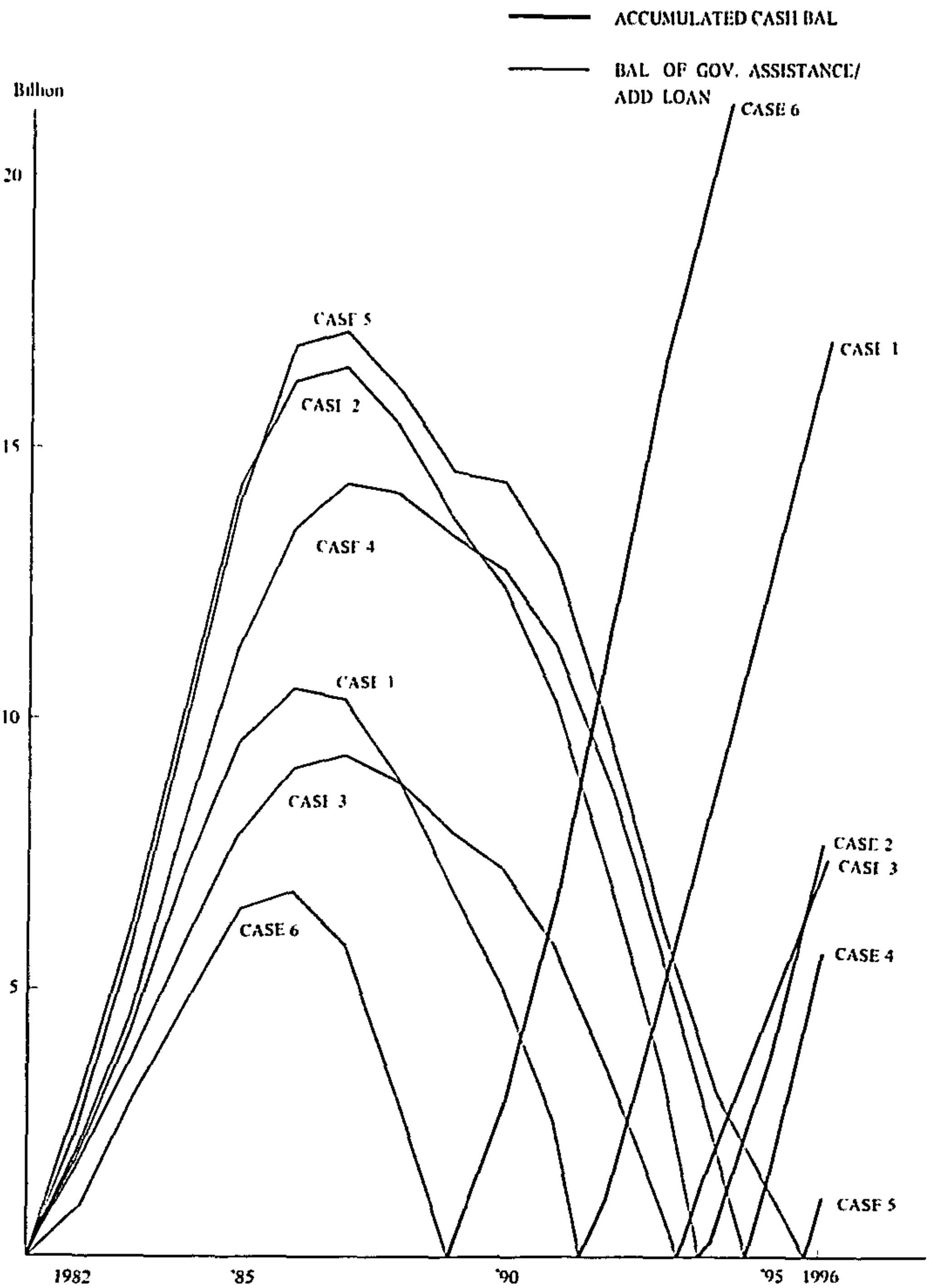


Fig. II-12-2. Accumulated Cash Flow & Government Assistance/Additional Loan

Table II-12-1. Comparison of Profit and Loss, Cash Flow Projections

(unit of amount: million pesos)	Case-1 (base case)	Case-2	Case-3	Case-4	Case-5	Case-6
Initial capital cost	20,741 (Alternative-B)	25,023 (Alternative-A)	16,092 (Alternative-C)	20,741 (Alternative-B)	22,780	20,741 (A)
Fare	4 pesos	4 pesos	3 pesos	4 pesos	1982~'86 4 pesos '87~'91 5 pesos '92~'96 6 pesos	5 pesos
Escalation	None	None	None	None	10% p.a. for capital cost and operating expense (from '79)	None
Add loan/Assistance interest	0%	0%	0%	8.75% p.a.	0%	0%
[I] Profit and Loss						
(1) Year profit first expected (Year from inauguration)	1984 (3rd year)	1985 (4th year)	1985 (4th year)	1985 (4th year)	1985 (4th year)	1983 (2nd year)
[II] Cash flow						
(1) Years Asst/Add loan required	5 years	6 years	6 years	6 years	6 years	5 years
(2) Total Asst/Add. loan	10,700	16,500	9,400	14,500	17,200	6,696
(3) Cash flow bal. first attained (= Year Asst/Add. loan fully repaid)	1992	1994	1994	1995	1996	1989
(4) Accumulated cash balance at 1996 yearend	17,000	7,700	7,400	5,600	1,000	32,540

13. Economic Evaluation

13-1 Conclusion

The Internal Rate of Return (I. R. R.), taken as the index for economic evaluation, becomes 13. 2%, and considering that the calculation was based on a conservative analytical method, we can conclude that this Project is sufficiently feasible from the economic point of view.

13-2 Economic Costs

(1) Initial Construction Cost ... Total funds required for the Project (Alternative B) minus interest (13, 316 million pesos)

(2) Cost for Right-of-Way... 1, 014 million pesos for the lands and the roadbeds which need to be restored.

(3) Additional Investment ... 5, 148 million pesos (Alternative B)

(4) Operational and Maintenance Costs ... 12, 196 million pesos

(5) Residual Value ... Book value at the end of the last year of the Project Life (1996) = 10, 521 million pesos {(1) + (2) + (3) - (13, 957 million pesos: Total sum depreciated till the end of 1996)}

13-3 Economic Benefits

(1) Considering that factors such as reduction of traffic accidents, travel comfort and air pollution are difficult to quantify and also that the availability of basic data is limited, the study and review were centered about the following two points:

- Reduction of transportation costs for users of the new facilities
- Savings in transport time for passengers

(2) Future Traffic Volume

The estimated future traffic volume which was used as the basis for the calculation of benefits is the total passenger transport distance by years (persons x km). This, in turn, is based on a separate computation of the estimated number of passengers.

(3) Traffic Cost

The following three items were calculated based largely on the basic data provided by the Mexican authorities.

a) Travel Costs

The following travel costs were computed for buses and passenger cars (automobile) taking into account the cost of fuel and assuming that other costs correspond to 50% of the fuel cost.

(in pesos/person x km)

	Buses	Passenger cars
Fuel	0.008	0.287
Others	0.004	0.144
Total	0.012	0.431

b) Fixed Costs

A simplified method was adopted whereby the purchase price of vehicles (tax deducted) is counted as a fixed cost.

	Buses	Passenger cars
Price (tax deducted)	890,330 pesos	101,568 pesos
Service life	7.5 years	9 years
Fixed Price per vehicle	118,711 pesos	11, 285 pesos

c) Time Cost

Time values were computed for all drivers and passengers of buses and passenger cars. Considering, however, that applying the minimum legal wage of 106 pesos per day uniformly
To all persons is unrealistic, distinctive time value were classified into:

(1) Working hours, (2) Commutation, (3) Leisure time.

The time value of users of passenger cars was assumed to be twice as high as for users of buses.

	Time value (pesos/hour)	
Purpose of use	Buses	Passenger cars
(1) Working hours 25%	13,250	26,500
(2) Commutation 50%	6,625	13,250
(3) Leisure time 25%	2,665	5,300
Weighted average (pesos/person x km)	7,288	14,575

(2) = (1) x 1/2, (3) = (1) x 1/5

d) Total Traffic Cost

The traffic costs for a) thru c) according to type of vehicles are as follows:

	Bus	Passenger car
Travel costs (pesos/person x km)	0. 012	0. 431
Fixed costs (pesos/vehicle x year)	118, 711	11, 285
Time costs (pesos/person x hour)	7, 288	14, 575

When totaling these costs, the units (pesos/person x km) become as follows:

	Bus	Passenger car
Fixed cost	0. 060	0. 086
Time cost	0. 486	0. 486

Time costs are based on a comparison with the use of roads, and the figures are obtained by subtracting the cost for the same unit for the use of railroads (bus 0. 138 pesos, passenger car 0. 275 pesos). That is, 0. 348 pesos for bus and 0. 211 pesos/person x km represent the effective savings in time costs.

Thus, the economic benefits resulting from the construction of railroads can be calculated as savings in traffic costs by types of vehicles as follows:

(in pesos/person x km)

	Bus	Passenger car
A. Travel cost savings	0. 012	0. 431
B. Fixed cost savings	0. 060	0. 086
C. Time cost savings	0. 348	0. 211
Total	0. 420	0. 728

13-4

So far we have limited our evaluation to economic benefits, but the importance of social benefits such as the reduction or restriction of exhaust gas, the reduction or prevention of noise pollution, the promotion of inter-community communications and balanced economic development among regions should not be forgotten. The evaluation of this Project preferably should include all such factors.

14. Education and Training Plan

As to personnel training, there is the need, at first to familiarize the management personnel and foremen with the new technology to be adopted, and then, train the general employees under their leadership. It is deemed that 4 to 6 months of training will be required for each job level. Furthermore, there is the need to complete a short section of track at least 6 months prior to the inauguration date, for use in actual training of field personnel.

15. Conclusion

The population of Mexico City Metropolitan Area already stands at 13 million and is continuing to show a high rate of increase. It is thus expected that the 25 million mark will be exceeded within this century, making this Metropolitan Area one of the hugest urban centers of the world.

Traffic congestions have already emerged in road transportation here, and air pollution by motorcar emission is becoming a serious hazard to the life of its citizens.

Such being the case, resort to road expansion only to meet the future transportation needs of the Area will require an exorbitant amount of funds, and besides, difficulties are foreseeable in controlling motorcar emission. Accordingly, in order to provide mass transportation most adapted to the situation, it has become imperative to resort to railway construction.

Construction of a suburban railway. 320 km in length, is being contemplated for Mexico City, and it is understood that the 5 lines, 77 km in length, taken up in the present survey is the first step toward the realization of this suburban railway network. Hence, extra precaution has to be taken in prescribing its construction standards, since they will be difficult to alter once they are determined.

The Survey Team is of the conviction that the suburban railway plan herein set forth, characterized by the outstanding capacity for high-speed mass transportation unmatched elsewhere in the world, and the extensive adoption of the latest technology, would be the most appropriate one for the future super-metropolis.

The present plan is based on the points agreed upon as the result of studies and exchange of opinion between the experts of the Mexican Government and the experts of the Japanese Survey Team. Further, the new technology adopted has all been put to practical use and proved in the railways of Japan; and hence, it is the outcome of long years of experience and not merely a paper plan.

Accordingly, the Survey Team is confident that the present plan is practical even in small details, and that upon completion of the project, it will fully meet the expectation of the citizens.

Alternatives have been given wherever relevant, differentiating the costly one (Alternative-A) and the less costly one (Alternative-B), and the Mexican authorities are invited to review them, along with the fare levels, to determine those considered most appropriate. In this connection, it is to be specially mentioned that while Alternative-B enables a reduction in initial construction cost, full consideration has been given so that there will be no detrimental aftereffect in the future.

Upon financial analysis of the 15-year period from the completion of the project, no special problem is seen on the operating side, as it is anticipated that with the fare level at 4 pesos, losses will be incurred for 3 years after inauguration of services under Alternative-A, and for 2 years under Alternative-B, and that thereafter, operating profits will increase yearly at a rising tempo. The problem rather lies in the cash flow, as replenishment of a considerable amount of funds will be required for 6 years under Alternative-A, and 5 years under Alternative-B, on account of operating losses after inauguration of services and redemption of loans. In this connection, aside from selection of A and B Alternatives and determination of the fare level, it is deemed worthy to consider the possibilities of such measures as shouldering by the Government the cost of grade separation, instead of recovering such a cost of a public nature from fares.

It might further be mentioned that it is the worldwide trend for central and local governments to provide grants for the construction of suburban railways in metropolitan areas.

It is worth noting that if the fare is assumed to be 5 pesos as in another alternative (Case 6), operational revenue, expenditures, cash flow and fund raising all will be greatly facilitated.

In concluding, the Survey Team extends its sincere thanks to the Government of Mexico and its related agencies for all the cooperation and assistance recdered to the team in conducting this survey, and looks forward to the day when this railway will become a reality, fully worthy of the trust and admiration of the citizens of Mexico City.

Ⅲ. Details

1. Development of Mexico Metropolitan Area and Necessity for New Transport System

1-1. Population of Mexico Metropolitan Area

The Mexico Metropolitan area consists of the Distrito Federal (with some 9 million population) and the State of Mexico (with some 4 million population) (as shown in Fig. III-1-1), and the Fig. III-1-2 shows the tendency of growth in population since 1950 and the estimated future population.

As seen from this Figure, the amount of increase in population of the State of Mexico since 1970 has been in excess of that of the Distrito Federal, and the regions with the increasing population are expanding towards the environs of the Metropolitan area in every direction except to the southwest.

The population of the Metropolitan area showed an explosive increase of the annual increase of 375 thousand in 1960 to 1970, and 640 thousand 1970 to 1976, and is expected to show this growing tendency from now on.

The Table III-1-1 gives the populations by regions and cities, so that the tendency of the growth in population may be available in detail by zones. The estimated amount of increase in population from 1976 to 1995 shows a tremendous growth on the level of a million, 2330 thousand at Netzahualcoytl, 1370 thousand at Naucalpan and 1000 thousand at Tlanepantla, followed by 720 thousand at Ecatepec, 650 thousand at Ixtapalapa and 630 thousand at G.A. Madero.

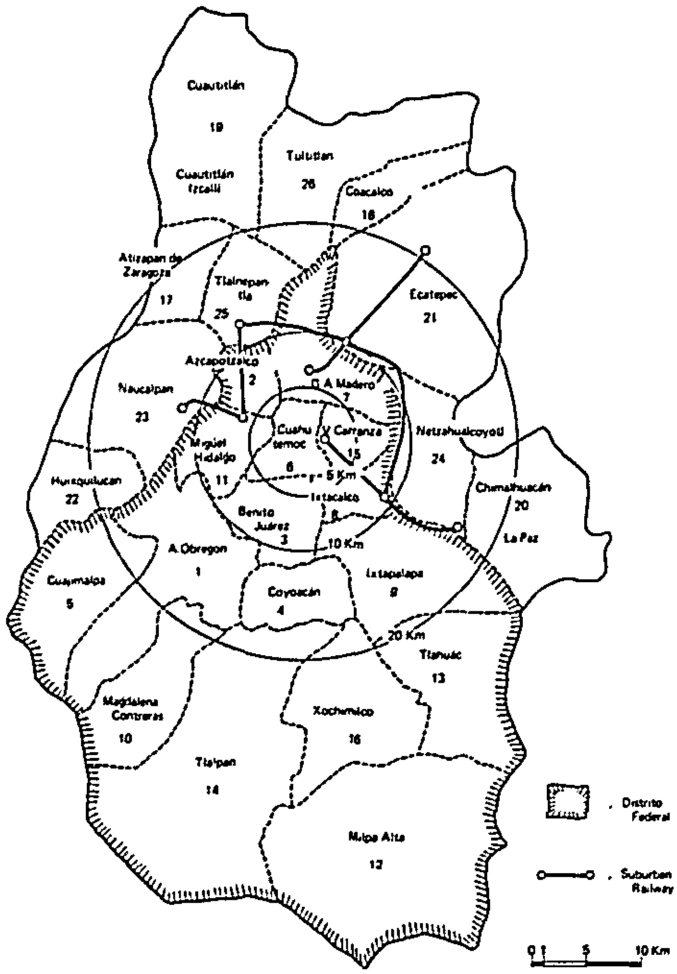


Fig. III-1-1. Mexico Metropolitan Area

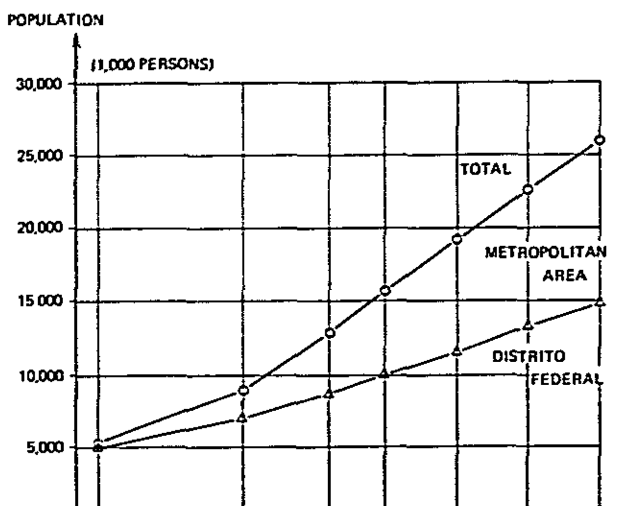


Fig. III-1-2. The Growth of Population in Metropolitan Area

Table III-1-1. Population by Zones (in 1000 persons)

Zone		1976		1980		1985		1990		1995	
1	Alvaro Obregon	650	100	780	120	910	140	1,020	157	1,100	169
2	Azcapotzalco	681	100	720	106	820	120	960	141	1,100	162
3	Benito Juarez	90	100	150	167	275	306	450	500	600	667
4	Coyoacan	400	100	490	123	675	169	770	193	830	208
5	Cuajimalpa	80	100	120	150	130	163	240	300	285	356
6	Cuahu Temoc	895	100	930	104	950	106	980	109	1,035	116
7	Gustavo A. Madero	1,800	100	1,950	108	2,150	119	2,300	128	2,430	135
8	Ixtacalco	600	100	650	108	740	123	800	133	850	142
9	Ixtapalapa	850	100	1,050	124	1,170	138	1,370	161	1,500	176
10	Contreras	120	100	175	146	260	217	350	292	430	358
11	Miguel Hidalgo	800	100	860	108	915	114	1,050	131	1,175	147
12	Milpa Alta	55	100	83	151	138	251	175	318	215	391
13	Tlahuac	90	100	150	167	275	306	450	500	600	667
14	Tlalpan	175	100	250	143	335	191	480	274	640	366
15	Venustiano Carranza	817	100	912	112	967	118	1,085	133	1,100	135
16	Xochimilco	193	100	275	142	405	210	615	319	750	389
17	Atizapan de Zaragoza	100	100	150	150	250	250	390	390	540	540
18	Coacalco	40	100	70	175	120	300	190	475	250	625
19	Cuautitlan	65	100	150	231	230	354	360	554	460	708
20	Chimalhuacan y la Paz	100	100	155	155	215	215	300	300	435	435
21	Ecatepec	480	100	660	138	800	167	970	202	1,200	250
22	Huixquilucan	70	100	90	129	145	207	200	286	245	350
23	Naucalpan	810	100	1,100	136	1,410	174	1,800	222	2,180	269
24	Netzahualcoyotl	1,320	100	2,050	155	2,700	205	3,200	242	3,650	277
25	Tlalnepantla	780	100	1,050	135	1,300	167	1,550	199	1,780	228
26	Tultitlan	110	100	145	132	200	182	270	245	325	295
	Total	12,171	100	15,165	125	18,485	152	22,325	183	25,705	211

1-2. The Present Situation of Urban Transportation and the Planning for the Future

As the means of urban transportation, the Mexico Metropolitan area has route buses, automobiles, subway, taxicabs, street cars, and trolley buses.

Buses have Delfine, Ballena and other bus lines. Table III-1-2 shows that the percentage of trips by buses amounts to 60% approximately, and that they are playing the main role in the urban transportation, followed by automobiles having the trip percentage of about 20%. The subway system, having the route network shown in Fig. III-1-3, has the trip percentage merely of some 10% but has a very high coefficient of utilization, being operated generally near the limit of carrying capacity, for the reason that the network is formed at the urban center and that the passenger fares are uniform over the whole route (1.2 pesos, but cheaper on a coupon ticket basis - 1.0 pesos). Trolley buses and street cars have very low percentages.

As the urban transport system for mass transportation, the subway system of about 40 km route length is rather small in scale for the big city of 13 million population. In the big cities of over millions of population in the world, suburban railways of a larger scale are operated generally as the main of urban transportation (Table III-1-3).

Suburban railways have the excellent characteristics never exceeded by other means of transportation in mass transportability, high speed, punctuality, safety, energy saving, prevention of air polution by exhaust fumes, and other aspects.

(1) Mass transportability

The suburban railway has the carrying capacity some 10 times as large as the buses, and some 40 times as large as automobiles (as seen from Table III-1-4).

(2) High speed running and punctuality

The existence of rights-of-way is generally said to be advantageous as the means of transportation. In case of through service between suburbs and the center of the city, the buses will be restricted by a traffic congestion for a long-distance service, but on the other hand the urban railway will be able to make full use of its characteristics.

(3) Safety

The suburban railway can be said to be far safer than buses.

(4) Energy savings

On a basis of energy consumption per passenger-kilometer as shown in Table III-1-5, the railway has a higher efficiency - 1/2 of buses and 1/6 of automobiles in energy consumption.

(5) Air polution by exhaust fumes

A vast improvement may be possible by governmental restrictions, but practically the decrease in air pollution by exhaust fumes will have its limit, when considering a big investment and engineering development required for such improvement.

For the improvement of traffic problems in the Mexico Metropolitan area, the Mexican Government has plans for the extension and enlargement of the subway network and for the construction of suburban railways with respect to the planning for the adjustment of railway systems for the future.

This policy points to the correct direction for the solution of the traffic problems in a big city, and it is urgent to settle a railway transport system suitable to the big city both for the subway and the suburban railway. Particularly the suburban railway project will be extremely efficient since the high-speed mass-transport facilities are to be introduced into the region new to the railway systems.

It is of urgent necessity to transport a great many passengers at high speeds from peripheral regions to near the center of the city, and therefore, desirable is the planning of a suburban railway system of low construction cost and with high carrying capacity.

Table III-1-2. Passengers Volume and Type of Transport in the Metropolitan Area of Mexico City

Mode	Number of Persons	Percentage
Motorbus (Bus)	3, 280, 000	59. 00
Troleybus & Streetcar	18, 000	0. 32
Taxi	56, 000	1. 01
Subway	133, 000	2. 39
Automobile	1, 101, 000	19. 81
Motorcycle	40, 000	0. 72
Other Combinations	355, 000	6. 39
Motorbus-Subway	576, 000	10. 36
Total	5, 559, 000	100. 00

Source; Basic data prepared by the Japanese mission.

Table III-1-3. Subways in Main Cities of the World

Description / City	Population (x 10^3)	Inauguration	Route kilometers	Number of routes
Tokyo (Japan)	8, 590	1927	163. 2	8
London (UK)	7, 300	1863	381. 1	8
New York (USA)	8, 000	1868	393. 5	—
Paris (France)	8, 100	1900	256. 1	19
Mexico city (Mexico)	8, 600	1969	37. 4	3

Source: Annual Urban Transport Report (1977)

Table III-1-4. Transportation Factor by Rail and Road

	Electric cars	Buses	Automobiles
Transportation conditions	10-car train 2m. 10s. headway	70-seat bus 1 m. headway	1.5 person/car 5 s. headway
One-way width of road or railway	5 m	4 m	4 m
Carrying capacity per hour per one way	39,200 persons (1)	4,200 persons (0.1)	1,080 persons (0.03)
Carrying capacity per hour per 1 m of one-way width	7,840 persons (1)	1,050 persons (0.13)	270 persons (0.03)

Note 1. The figures in ( ) show the ratio of carrying capacity

2. Figures for electric railcars correspond to the JNR CHUO Line in Tokyo.

3. Source: "Prospect for Total Traffic System - Traffic Planning" (by author Dr. Misao Sugawara, published by Sankaido), for statistics of buses and automobiles.

Table III-1-5. Energy Consumption per Unit Transportation (with load factor taken as 100)

Means of transport	Loading	Kcal/passenger-kilometers
Buses	50 persons	60
Automobiles	5 persons	190
Electric railcars	144 persons	30

Source: "Manual for Economic Statistics on Transportation" edited by the Ministry of Transport.

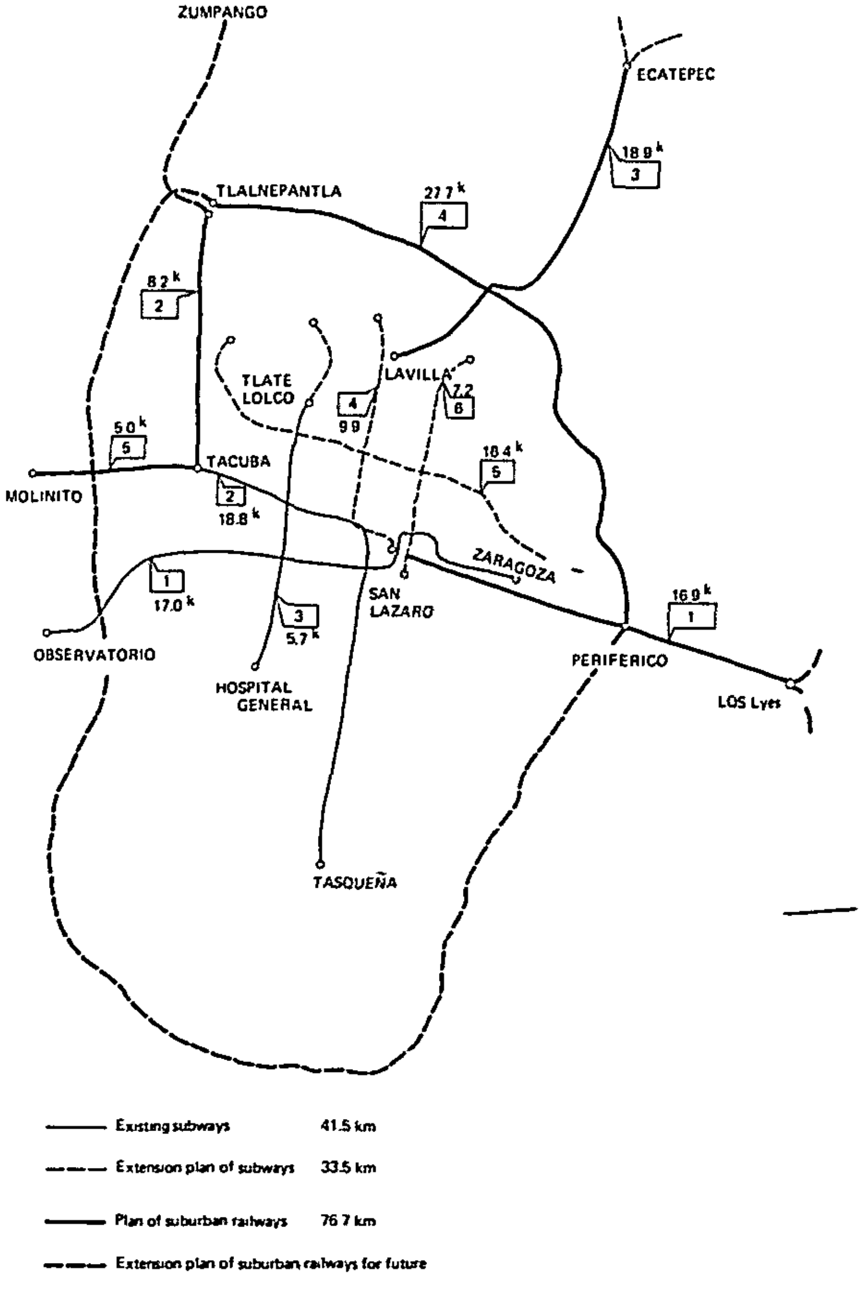


Fig. III-1-3. Plans for Construction of Subways and Suburban Railways Metropolitan Area of Mexico City

2. A Plan of Suburban Railways

2-1 Route Planning

This railway aims at high speed transportation of a great number of passengers arising between suburbs and the midtown area, and is planned in consideration of the flow of passenger, connection with other means of transportation and the tendency of the urban development as described hereunder.

Incidentally, this route-planning is specially characterized in utilizing lands of abolished National Railway, and can be said to be quite a practical plan. (App. Fig. III-2-1).

2-1-1 Route No. 1

This is a route of about 17 Km, starts from San Lazaro in Venustiano Carranza Ward which is a ward of old Mexico City making its way to east-southeast through Ignacio Zaragoza Street to Los Reyes.

The route runs parallel with existing No. 1 subway for about 2 Km from the start, and attention is given for the connection of this railway with the subway. Along with this line, low storied houses are being crowded in Netzahaulcoytl, whose population is said to be 1. 3-millions.

The line has two future extension plans; the one is to go forward from Los Reyes to Cholco and the other from Los Reyes to Teotihuacan through Texcoco.

2-1-2 Route No. 2

This is a route of about 8 Km advancing northwards from the existing No. 2 subway terminal Tacuba to Tlalnepantla.

Along this line, the urbanization is progressing in this district, specially Tlanepantla is becomming a key point of north industrial district.

The line is planned to advance northwards to Zumpango where the Second International Air Port is being planned to serve to the development of the background of Guadelupe Mountain.

2-1-3 Route No. 3

This is a route of about 19 Km starting from La Villa which is located to immediately south of the Temple Guadalupe and advances north-northeast through Xalostoc to Ecatepec.

Around the starting terminal of this line is urbanized to a certain extent, and many plants are located along the line from Xalostoc to Ecatepec.

This line has also two future extension plans, the one is from around

Ecatepec to Teotihuacan and the other is from Ecatepec to Zumpango.

2-1-4 Route No. 4

This is a route of about 28 Km starting from Periferico Station of Route No. 1 passing through the east side of the airport, then crossing and advancing northwards along with the existing National Railway Line, crossing the Route 3 at Xalostoc then advances westwards to Tlalnepantla.

About 5 Km of the starting area and about 6 Km of the ending area of the route are scheduled to be constructed on road and waterway bed.

The eastern part of this route has soft ground area and where a large scale housing developments are being carried out.

The route is scheduled to extend to the south district to form a large roop-route surrounding the metropolitan area.

2-1-5 Route No. 5

This route is a new plan added most recently starting from Tacuba, which is the starting point of the Route No. 2, to Molinito. However, the detailed route and the location of the stations are yet to be decided.

An on-the-spot survey of the route has resulted in the two plans:

(1) A route goes straight through Tacuba Station to Mexico-Tba Street then advances westwards passing south side of Toreo and the outside of the Army Base to Molinito.

(2) A route to turn back at Tacuba Station and advances along the existing National Railway to Toluca through Naucalpan to Molinito.

Considerations on these plans are as following:

Plan (1) permits the through operation between route 2 and route No. 5 enabling efficient transportation. However, in this case, total necessary land should be purchased. The structures of the section between Tacuba and Toreo seems most appropriate to be continuous elevated railway, because the section is densely populated urbanized area. From this, the construction cost will become high and construction works will become difficult.

Plan (2) is to set the route on the existing National Railway land. However, this existing line is one of the most important among the National Railway lines and the future reinforcement of the line is being planned. Consequently the suberban railway shall be placed to leave a room for the reinforcement of present line. This plan seems to have less problems in securing land and construction compared with the plan (1) with the merit to pass through densely populated Maucalpan. On the other hand, it has a weak point of making the layout of Tacuba Station complicated and the connection to No. 2 route will have to be made to be the switch-back style.

Other than mentioned in above, both plan (1) and plan (2) have a common drawback locating the terminal station a little too far from the present subway and causes inconveniences for transfer.

Anyway, sufficient study is required for the selection of the route and location of stations on the route No. 5 because this route costs more and construction difficulties are greater compared with other four routes.

The track diagrams shown in the App. Fig. III-6-1 and III-6-2 are of plan (1).

2-2 Arrangement of Stations

2-2-1 Matters to be taken into Consieration

A location of station affects the convenience of users and the development of the city in a great deal. Because of its importance, the planning of the location of a station shall be performed with full consideration of the following:

- * Station sphere
- * Number of passengers
- * Flow of passengers
- * Connection of transport facilities
- * City development plan

2-2-2 Location of Stations

In the case of this railway project, locations of stations are almost determined by Mexican side.

According to the plan, the distance between stations was determined to 5.0 Km for the maximum, 1.2 Km for the minimum and the average 2.6 Km as is shown in the Table III-2-1.

These arrangements of stations are considered adequate taking future population increase and the actual results of Japanese suburban railways into account. (Table III-2-2)

Table III-2-1 Station Arrangements

Line	Operating Length	Number of Stations	Max. Distance between Stations	Min. Distance between Stations	Average Distance between Stations
No. 1	16.9 Km	8	2.9 Km	1.9 Km	2.4 Km
No. 2	8.2	4	3.6	2.3	2.7
No. 3	18.9	9	5.0	1.2	2.4
No. 4	27.7	11	4.4	2.0	2.8
No. 5	About 5	2	—	—	2.5
Total	76.7	34			2.6

Table III-2-2 Station Arrangements in Tokyo Metropolitan Area

Operator	Lines	Sections	Distance	Number of Stations	Average Distance between Stations
			Km		Km
JNR	Yamanote	Around Tokyo	34.5	29	1.2
	Keihin-Tohoku	Akabane-Yokohama	42.0	26	1.7
	Chuo (Rapid service)	Tokyo-Mitaka	24.1	12	2.0
	Sobu (Local service)	Chiba-Ochanomizu	38.7	20	2.0
	Sobu (Rapid service)	Tokyo-Chiba	39.2	9	4.9
Tokyu	Toyoko	Shibuya-Sakuragicho	26.3	23	1.2
Seibu	Ikebukuro	Ikebukuro-Tokorozawa	24.9	16	1.7
Tobu	Tojo	Ikebukuro-Kawagoe	30.5	18	1.8

3. Estimate of Traffic Demand

3-1. Demand Estimation Method

The process of demand estimation is as shown in the Fig. III-3-1.

Based on the O. D. table furnished by Mexican side and other material, COPLINTRA used in estimating demand, the traffic demand is formed as follows taking population increase into consideration;

(1) O. D. table for each station

(2) Number of passengers by section between stations per day, by year and by route

(3) Number of passengers per year and by route

(4) The maximum number of passengers during peak hours by section between stations by year and by route

3-2. Target Years and Areas for the Estimation

* Target years for the estimation of traffic demand are: 1982, 1985, 1990, 1995.
* Areas for the estimation of traffic demand are the districts along the suburban railways as shown in Fig. III-3-2.

3-3. Estimate of Traffic Demand

3-3-1. Preparation of O. D. Table

For the estimation of traffic demands, O. D. table of 26-zones in the year of 1976 (Table III-3-1) is used as the basis. The O. D. table does not give the number of trips, but shows the number of people residing in the origin zones and the people working in the destination zones by paired-zone.

In converting the value into trip numbers, COPLINTRA's convert estimation method is adopted. The assumption is as follows: The ratio of workers and non-workers is assumed to be 1:1. Trip number of workers is assumed to be 2.2 trips/person·day for commutation and 0.7 trips/person·day, for business trip. And non-workers are classified into houswives, students and others and their numbers are assumed to be in the ratio of 0.6 : 0.3 : 0.1 with the trip frequency of each 1.0 trip/person·day, 2.0 trip/person·day, and zero trip/person·day. This makes the average value of total population to be 2.05 trip/person·day. The value seems to be reasonable judging from results of the study made by subway

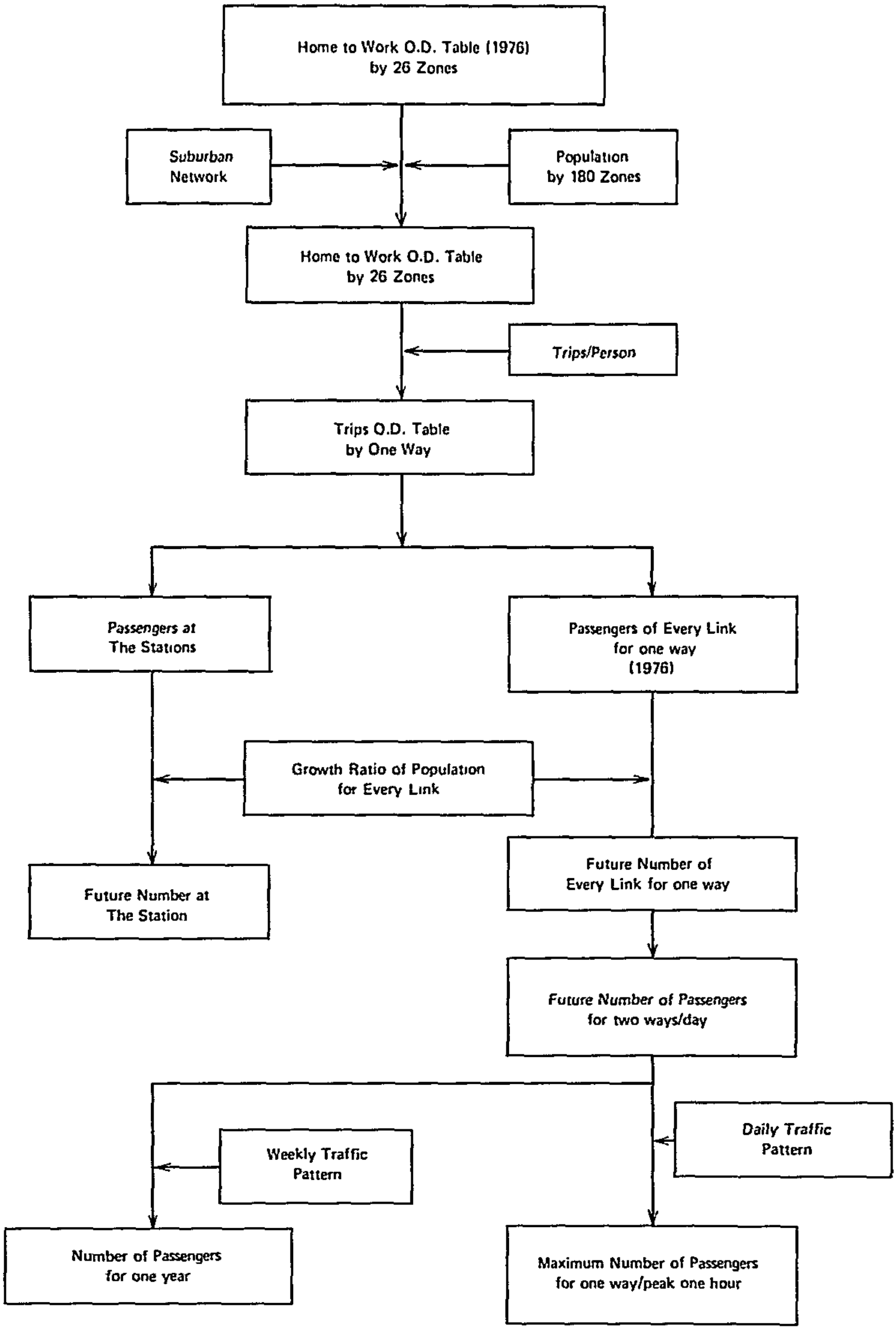

Home to Work O.D. Table (1976)
by 26 Zones
Suburban
Network
Population
by 180 Zones
Home to Work O.D. Table
by 26 Zones
Trips/Person
Trips O.D. Table
by One Way
Passengers at
The Stations
Passengers of Every Link
for one way
(1976)
Growth Ratio of Population
for Every Link
Future Number at
The Station
Future Number of
Every Link for one way
Future Number of Passengers
for two ways/day
Weekly Traffic
Pattern
Daily Traffic
Pattern
Number of Passengers
for one year
Maximum Number of Passengers
for one way/peak one hour

Fig. III-3-1

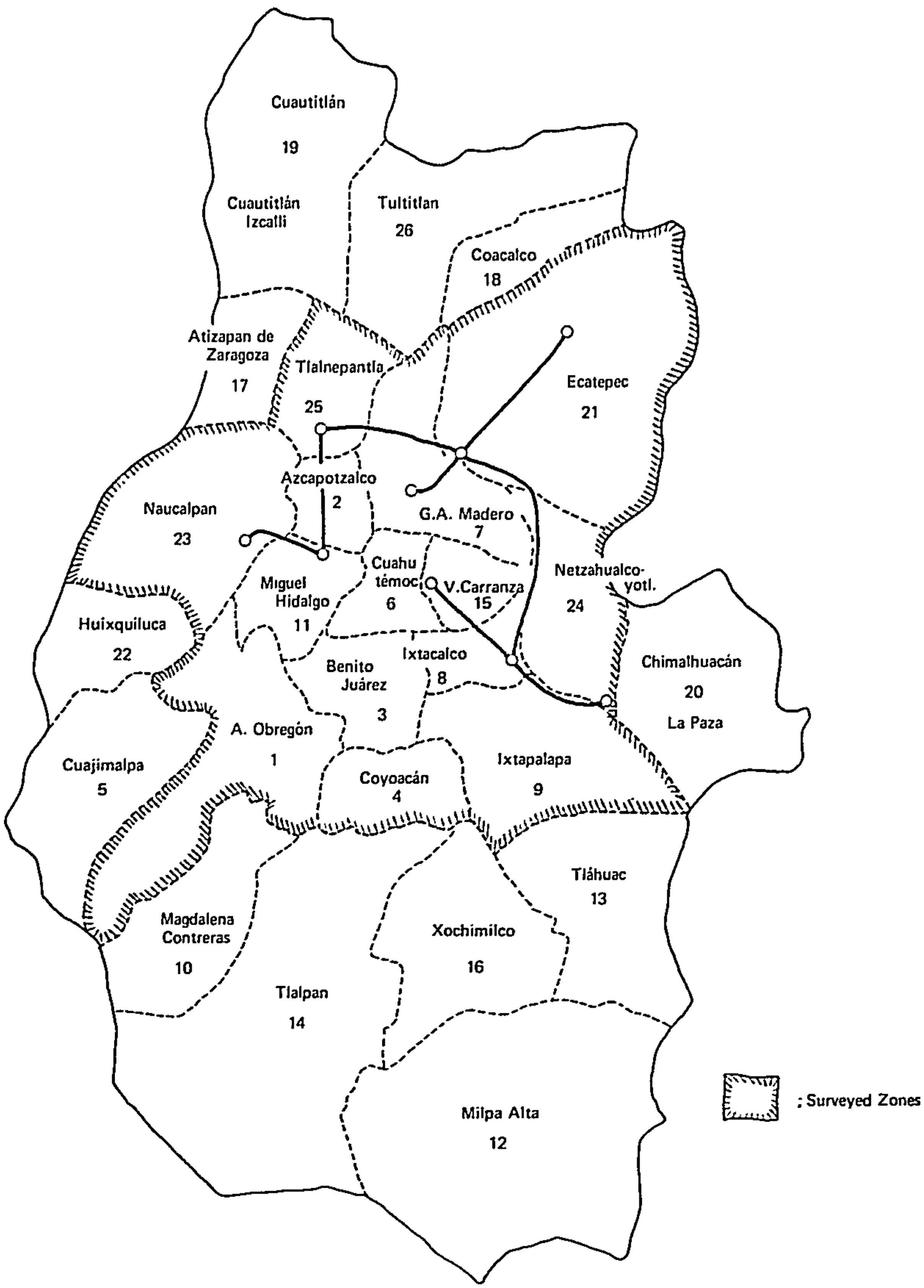


Fig. III-3-2 Mexico Metropolitan Area Zone Number

Table III-3-1 O. D. Table

Zone Number	Origin \ Zone Number / distiration	1 A. Obregón	2 Azcapotzalco	3 Benito Juárez	4 Coyoacán	5 Cuajimalpa	6 Cuahutémoc	7 G.A. Madero	8 Ixtacalco	9 Ixtapalapa	10 Magdalena Contreras	11 Miguel Hidalgo	12 Milpa Alta	13 Tláhuac	14 Tlalpan	15 V. Carranza	16 Xochimilco	17 Atizapánde Zaragoza	18 Coacalco	19 Cuautitlán Izcalli	20 Chimalhuacán	21 Ecatepec	22 Huixquilucan	23 Naucalpan	24 Netzahualco-yotl	25 Tlalnepantla	26 Tultitlán	Total
1	A. Obregón	43	2	21	10	2	31	10	2	6	1	11			5	2	1					1		7		1		156
2	Azcapotzalco	1	100	8	1		34	18	2	3		16	1	2		5				1		2		24		9		227
3	Benito Juárez	5	4	61	8		81	15	5	4		26		1	3	18	2			1		1		3	3	1		242
4	Coyoacán	6	4	18	42		27	4	3	2		8	1		15		1							1		1		133
5	Cuajimalpa					6	2					3																11
6	Cuahutémoc	6	13	40	8	1	299	26	9	7		47			3	34	1			1		2	1	7	5	6	1	517
7	G.A. Madero	4	23	15	7		69	131	4	10		17	1	1	5	17	2			1		12	1	12		18	1	351
8	Ixtacalco	3	7	14	3		41	6	33	6		7			1	9	2		1	1		1		4	1			140
9	Ixtapalapa	8	11	12	15		52	7	16	80	1	16			5	8	1	1		1		1		1	2	2		240
10	Magdalena Contreras	2		2	2		4	1		1	4				1				1									18
11	Miguel Hidalgo	4	12	17	5	2	80	7	3	3	1	92			1	12	1		1	1		1		9	1	4	1	258
12	Milpa Alta			1					1				5				1											8
13	Tláhuac		1				2			1		1	1	14	3													23
14	Tlalpan	7		11	3		13	1	1	2	2	5			32	3	1					1		1		1		84
15	V. Carranza	5	5	18	10	1	83	21	7	5		30			2	53	1		1	1		1		3	2	4	1	254
16	Xochimilco	2		4	1		6	1		7		1	1		5	1	18									1		49
17	Atizápande Zaragoza		1	2			4	2		1		3	4	2				5	1	1		1		4		3		34
18	Coacalco	1		1			4	2	1					1					4					1		1	1	17
19	Cuautitlán Izcalli		1					2											1	17				1	1	2	3	28
20	Chimalhuacán	1		2			4			2		1									11	1			2	1		25
21	Ecatepec		12	7	2	1	21	17	1	1		6				8			1			85		1	1	7	1	172
22	Huixquiluca				2		5					3										2	7					19
23	Naucalpan	3	20	8	4		30	4		2		32		1		4	1			2		2		140	1	12		266
24	Netzahualco-yotl	8	20	13	8		49	29	14	16	1	23		2	3	24	3			1		8		7	52	4		285
25	Tlalnepantla	1	16	9	2		34	22	3	1	1	12	1			6	1			2		15		17	1	73		217
26	Tultitlan		1				1	1												2				1			8	14
	Total	110	253	284	133	13	976	327	105	160	11	360	15	24	84	204	37	6	11	33	10	137	9	244	72	151	17	3,787

BASIC DATA REQUIRED BY THE JAPANESE MISSION (POBLACION DE 12 ANOS Y MAS SEGUN LUGAR DE RESIDENCIA Y TRABAJO 1976) authorities of Mexico City. Consequently, the number of trips by the residents of a zone, which includes workers numbering A will be;

A x (2. 2 + 0. 7) + 0. 6A x 1. 0 + 0. 3A x 2. 0 = 4. 1A trips.

Assuming that the number of departing trip is equal to that of arriving trip, the number of trips arising from the residents of each zone becomes 2. 05A trips.

As O. D. table by trip-purpose is not available O. D. pattern of Table III-3-1 is applied temporarily, to get O. D. table of one-way trip multiplying the 26-Zone O. D. value by 2. 05.

This one-way-trip O. D. table is broken down into small zones so that one zone constitutes one station zone of the suburban railway. The data used for this calculation are the population survey results of 180 metropolitan zones of Mexico City. The population ratio of each station-zone calculated from this data is used to prepare O. D. table of small zones.

3-3-2. Rate of Railway Users

The data of railway users by paired-zone are not available. The only data available are those arising by zone and by mode of transport. (Table III-3-2). In this table, zones with the mark of * are the zones where subways are passing. The rate of subway users of these zones is indicated as 20. 8% to 27. 7%. Assuming that railway users of paired-zone of long distance will increase, the rate is assumed to be 30%.

3-3-3. Assumption of Traffic Volume by Section

The traffic volume by section obtained by distributing the value of one-way-traffic O. D. table (OD table between stations) of suburban railway on suburban railway network, which is prepared by the rate of railway users and O. D. table between short-distance zones, is an estimates value of traffic on the assumption that the suburban railway is existing in the year of 1976 when the O. D. table of 26 zones is made. Consequently, the value should be modified to the value for future. Because of the difficulty in assuming the number of workers for classified working areas, working out of O. D. table for future is given up here. Instead, the traffic volume for the future is estimated by applying the rate of population increase along each line to the above traffic volume by section. The railway passengers in the first year of operation are assumed to be 70% of the first estimation value.

The O. D. tables described in the above are for one-way traffic; the trips

Table III-3-2. Modal Split of the Home to Work Trip in Metropolitan Area of Mexico City

	Zone	Automóvil	Autobús	Tranvia' o Trolebus	Taxi	Metro I	Transporte Escolar	Otro	Autobús y Metro II	Otras CombinacionesIII	Insuficientemente Especifiaoo	Total	I + II + III
	Area Metropolitana de la Ciudad de Mèxico	19.8	59.0	0.3	1.0	2.4	0.6	1.2	10.3	5.3	0.1	100.0	18.0
1	Alvaro Obregon	25.8	62.2	-	0.6	1.1	0.3	0.3	4.7	4.7	0.3	100.0	10.5
2	Azcapot-Zalco	9.5	74.6	0.3	0.6	0.6	0.3	2.2	8.6	3.0	0.3	100.0	12.2
3	Benito Juarez*	25.4	48.2	0.6	1.8	6.5	0.6	0.6	10.7	5.6	0.0	100.0	22.8
4	Coyoacan*	25.3	52.2	0.4	0.4	2.4	0.4	0.5	9.0	9.4	-	100.0	20.8
5	Cuajimalpo	11.1	55.6	-	11.1	-	-	-	22.2	-	-	100.0	22.2
6	Cuahu Temoc*	21.6	47.0	0.9	1.3	7.3	0.6	0.7	14.3	6.1	0.2	100.0	27.7
7	Gustavo A. Madero	11.9	67.2	0.3	1.0	0.8	0.3	1.0	13.2	4.3	-	100.0	18.3
8	Ixtacalco*	20.0	51.7	-	2.5	2.0	1.5	1.9	13.4	7.0	-	100.0	22.4
9	Ixtapalapa	10.9	57.3	0.5	1.9	1.3	0.3	1.6	11.9	14.3	-	100.0	27.5
10	Contreras	3.6	92.9	1.8	-	-	-	-	-	-	1.7	100.0	0.0
11	Miguel Hidalgo*	25.4	45.0	0.3	2.3	6.8	1.6	0.6	12.2	5.5	0.3	100.0	24.5
12	Milpa Alta	-	75.0	-	-	-	-	-	12.5	12.5	-	100.0	25.0
13	Tlahuac	5.6	88.8	-	-	-	-	-	0.0	5.6	-	100.0	5.6
14	Tlalpan	23.5	69.1	0.6	-	-	-	0.6	3.7	2.5	-	100.0	6.2
15	Venustiano Carranza*	21.5	47.8	0.8	1.6	6.9	1.1	1.0	12.4	6.9	-	100.0	26.2
16	Xochimilco	9.9	73.2	-	2.8	-	-	-	9.9	4.2	-	100.0	14.1
17	Atizapan de Zaragoza	31.1	59.0	-	1.6	-	-	1.8	1.6	4.9	-	100.0	6.5
18	Coacalco	41.0	35.9	-	2.6	-	2.6	-	17.9	0.0	-	100.0	17.9
19	Cuautitlan	22.2	74.6	-	-	-	-	3.2	-	0.0	-	100.0	0.0
20	Chimalhuacan y la Paz	7.5	70.0	-	-	-	-	2.5	20.0	-	-	100.0	20.0
21	Ecatepec	12.2	79.1	-	-	-	0.6	1.1	4.7	2.3	-	100.0	7.0
22	Huixqui-Lucan	94.4	5.6	-	-	-	-	-	-	-	-	100.0	0.0
23	Naucalpan	30.7	61.6	-	-	-	1.0	1.5	2.5	2.7	-	100.0	5.2
24	Netzahu-Alcoyotl	7.5	63.1	-	-	-	0.3	1.7	24.1	3.3	-	100.0	27.4
25	Tlalne-Pantia	30.9	57.5	-	0.6	-	1.1	0.5	4.0	5.4	-	100.0	9.4
26	Tutitlan	10.5	84.2	-	-	-	-	5.3	-	-	-	100.0	0.0

from residential areas to working areas. That is, that the traffic volume by section and boarding and alighting passengers correspond to one-way-traffic volume.

The traffic volume of both ways by section per day estimated for 1982 is shown in Fig. III-3-3.

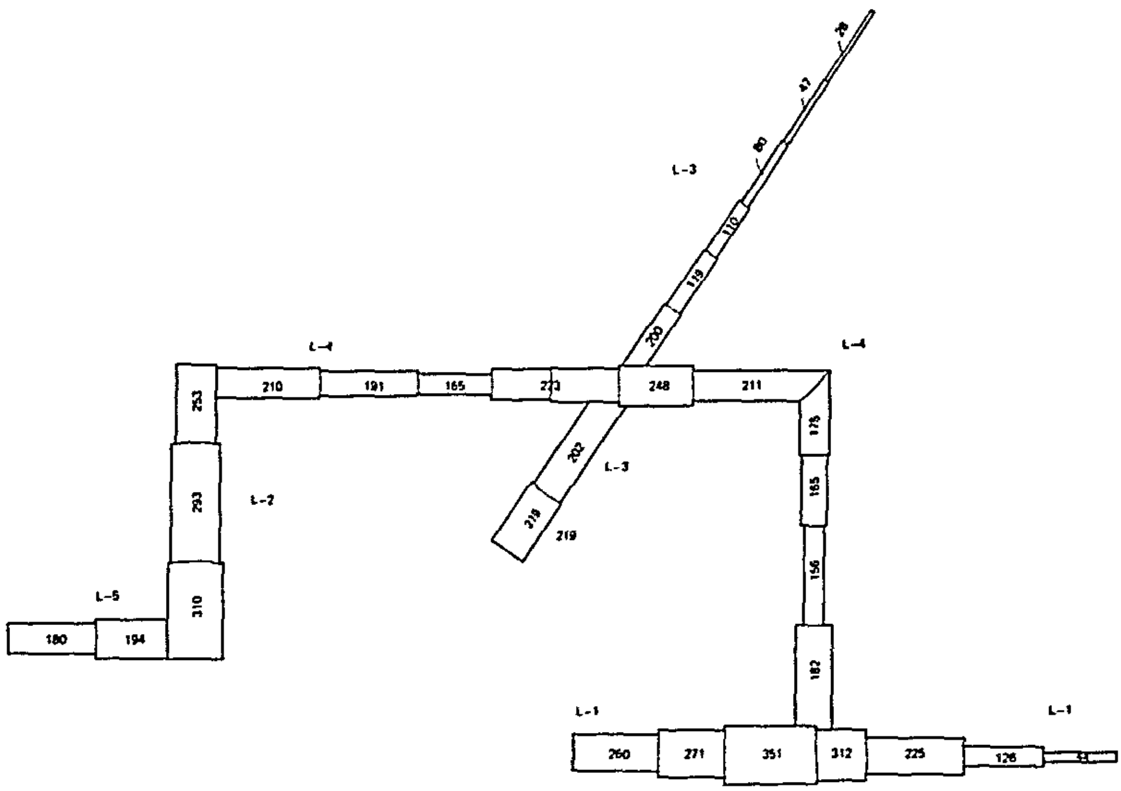


Fig. III-3-3. Number of Passengers (1982)
(1000 passengers/1 day for both ways)

The traffic volume estimated by section yearly are as shown in the tables III-3-3 through III-3-7. Although, the passengers on line 1 and on subway can transfer at stations of R. CHRUBUSCO, I. ZARAGOZA and SAN LAZARO, it is assumed that the passengers heading for city center will transfer at R. CHURUBUSCO and those for opposite direction, at SAN LAZARO.

Table III-3-3. Number of Passengers

(1000 passengers/day for both ways)

Section \ Year	1982	1985	1990	1995
Los Reyes				
	44,445	68,918	83,715	98,151
Ermita Zaragoza				
	125,517	194,632	236,422	277,189
Las Torres				
	225,109	349,064	424,013	497,127
Telecommunicaciones				
	312,006	483,809	587,689	689,027
Periferico				
	350,523	543,536	660,240	774,089
R. Churubusco				
	271,409	420,858	511,223	599,375
I. Zaragoza				
	259,624	402,583	489,024	573,349
San Lazaro				

(Line 1)

Table III-3-4. Number of Passengers

(1000 passengers/day for both ways)

Section \ Year	1982	1985	1990	1995
Tlalnepantla				
	252,862	400,365	465,439	534,853
Valle de Mexico				
	293,368	464,500	539,999	620,531
Atzcapozalco				
	310,488	491,606	571,511	656,743
Tacuba				

(Line 2)

Table III-3-5. Number of Passengers

(1000 passengers/day for both ways)

Section \ Year	1982	1985	1990	1995
Ecatepec				
	27,620	42,452	48,122	54,021
Tulpetrac				
	46,727	71,819	81,410	91,391
Sta. Clara				
	80,230	123,313	139,780	156,918
Diazordaz				
	110,130	169,269	191,873	215,397
Rustica				
	119,365	183,463	207,962	233,459
Xalostoc				
	200,349	307,935	349,056	391,852
C. T. M.				
	201,991	310,459	351,918	395,064
Carrera				
	219,020	336,631	381,585	428,369
La Villa				

(Line 3)

Table III-3-6. Number of Passengers

(1000 passengers/day for both ways)

Section \ Year	1982	1985	1990	1995
Tlalnepantla				
	209,998	337,920	427,823	512,806
Tenayuca				
	190,955	307,277	389,027	466,304
Progre so Nacional				
	165,020	265,543	336,190	402,971
Ticoman				
	222,787	358,500	453,878	544,037
Xalostoc				
	247,821	398,783	504,878	605,168
San Felipe				
	211,237	339,914	430,348	515,833
Impulsora				
	174,861	281,378	356,239	427,002
Aragon				
	164,607	264,878	335,349	401,963
Cuchilla del Tesoro				
	156,494	251,823	318,820	382,151
Arenal				
	182,260	293,285	371,313	445,071
Periferico				

(Line 4)

Table III-3-7. Number of Passengers

(1000 passengers/day for both ways)

Section \ Year	1982	1985	1990	1995
Tacuba				
	193,692	305,602	359,519	418,872
X				
	179,789	283,667	333,714	388,808
Moiinito				

(Line 5)

3-3-4. Number of Passengers by Year

The number of passengers on each line can be calculated from the number of passengers of each station. In order to calculate the number of passengers per year, the following assumptions are employed.

365 days in the year	
240 weekdays	Number of users 100%
73 Holidays	Number of users 73%
52 Saturdays	Number of users 87%

The rates of users on Saturdays and holidays to the rate of weekdays are assumed from the actual conditions of subway.

The assumed total number of users of each line per year is for the calculation of yearly passenger revenue. The passengers riding on two or more lines are counted for the line of boarding station. Results of the calculation are shown on the Table III-3-8.

Table III-3-8. The Assumed Number of Boarding Passengers by Routes

(unit: 1000 persons)

Year \ Route	L_1	L_2	L_3	L_4	L_5	Total
1982	237, 465	107, 540	91, 370	89, 891	63, 325	589, 591
1985	368, 222	170, 273	140, 435	144, 646	99, 912	923, 488
1990	447, 286	197, 950	159, 189	183, 131	117, 539	1, 105, 095
1995	524, 413	227, 468	178, 707	219, 508	136, 944	1, 287, 040

Note) 1. The values in this table are yearly total

2. The classification of days of a year, 240 weekdays, 73 holidays, 52 Saturdays, Total 365 days

3. Flactuation rate of the days of the week, week day 100%, holiday 73%, Saturday 87%.

4. Values for the junction stations of each route are summed up as follows: PERIFERICO as L_1, XALOSTOC as L_3, TLALNEPANTLA as L_2, TACUBA as L_2

3-3-5. Concentration Rate in Peak Hours

COPLINTRA's estimation method for Concentration Rate in peak hours is as follows:

The number of passengers in one-way per day $T_1/2$

T_1 = Both ways traffic volume by section

The number of commuters per day $T_2 = 0.7\ T_1$

Directional rate of commutation traffic $g = 0.9$

Morning rush hours 3 hrs.

One hour traffic in the morning $= 0.7\ T_1 \times 0.9 \times 1/3 = 0.21\ T_1/2$

From the above assumption, one-way peak traffic is taken as 21% of the whole day traffic in one-way.

On the other hand, traffic concentration rate at rush hours is assumed to be 17% by the person-trip survey in Mexico Metropolitan area.

From the above, assumption is made that 21% as the upper limit value and

17% as the lower limit value.

The upper and lower limit values of the maximum, by-section traffic volume in rush hours for each line are given in the Table III-3-9.

Table III-3-9. Maximum Number of Passengers for One-Way / Peak One Hour

Route	Section	Maximum Number of Passengers for One Way / Peak One Hour				
			1982	1985	1990	1995
L_1	Perifico - Telecomunicaciones	A	36,805	57,701	69,325	81,279
		B	29,795	46,200	56,120	65,797
L_3	La Villa - Carerra	A	22,997	35,346	40,066	44,979
		B	18,617	28,613	32,434	36,412
L_4	Sanfelipe - Xalostoc	A	26,021	41,872	53,012	63,543
		B	21,065	33,896	42,914	51,440
L_2 & L_5	Tacuba - Atzco Pozalco	A	32,601	51,619	60,009	68,958
		B	26,391	41,787	48,579	55,823

Note: A: Alternative-A

B: Alternative-B

4. Train Operation Plan

4-1 Basic Concept in Planning Train Operation

4-1-1 Transportation Plan

For the determination of train operation plan for a suburban railway, transportation shall be executed to match with the transport demand of the passengers attaching importance to that of commuters, in consideration of the following factors :

(1) Establishment of the train frequency (transportation capacity) to cope with the transport demand

(2) Establishment of transportation capacity to cope with the fluctuating transport demand in accordance with the time in a day, and the day in a week

(3) Determination of reasonable train consist

Table III-4-1 shows the whole day traffic volume obtained by an traffic demand estimate by year and route.

Table III-4-1 Whole Day Traffic Volume by Year and Route (Both Ways)

Unit: person

Route	Maximum Section	1982	1985	1990	1995
Line 1	Periferico — Telecommunicaciones	350,523 (100)	543,536 (155)	660,240 (188)	774,089 (221)
Line 3	La Villa — Carrera	219,020 (100)	336,631 (154)	381,585 (172)	428,369 (196)
Line 4	San Felipe — Xalostoc	247,821 (100)	398,783 (161)	504,878 (204)	605,168 (244)
Line 2 and Line 5	Tacuba — Atzcapozalco	310,488 (100)	491,606 (158)	571,511 (184)	656,743 (211)

Note: Figures in parentheses show the index number making the value of 1982 as 100.

According to the Table III-4-1, taking the traffic of the opening year of 1982 as the basis, the highest expansion rate is indicated at Line No. 4 (about 2.2 times in the year of 1995) and the lowest at Line No. 3 with the rate of about 2.0.

The traffic is busiest on the Line No. 1 and the least on the Line No. 3.

As the time-wise fluctuation of traffic is large for commuter transport and large number of passengers concentrate within several hours in morning and evening, adequate measures should be established to carry out the safe transportation.

Traffic estimate shows that the figures indicating concentrating rate of passengers in an hour of rush hour time against single way whole day traffic is 21% as the upper limit and 17% as the lower limit, and the use of these figures is reasonable. Therefore, train operation plan and the determination of required car number will be made hereafter making the case of 21% as alternative-A and that of 17% as alternative-B.

According to the dimensions of the car, it is reasonable to make 3-cars consisting of two motored cars and one trailer, a unit of the fixed train consists of 6-cars, 9-cars and 12-cars (cars with driver's cab shall be located only to the both ends of the train). One car can accommodates average 350 passengers.

The transportation capacity at the beginning of operation is sufficient with 6-cars except 9-cars for alternative-A of the Line No. 1. And the increasing transport demand for future shall be met with by extension of train consist and reducing train intervals.

Standing on the above described condition, the transportation plan by year and line for the cases of alternative-A and alternative-B are shown in Table III-4-2 and Table III-4-3 respectively.

The transportation plan is established for each line to cope with the section of largest amount of traffic.

Although Tacuba Station is the junction station of Line No. 2 and Line No. 5, thorough-train operation of Line No. 2 and Line No. 5 is planned, because the establishment of terminal station at Tocuba is quite difficult in consideration of geographical limitation around Tacuba Station and the requirement that Tacuba Station should not be too much apart from the subway Tacuba Station.

Flactuation of traffic by day in a week is predicted to be 87 point on Saturday

Table III-4-2 Transportation Plan in Rush Hour (Alternative-A)

Route	Item	1982	1985	1990	1995
Line 1	Passing passengers (persons/hr.)	36,805	57,071	69,325	81,279
	Train consist x number of train/hr.	9x12	9x18	12x16	12x19
Line 3	Passing passengers (persons/hr.)	22,997	35,346	40,066	44,979
	Train consist x number of train/hr.	6x12	6x17	6x19	9x15
Line 4	Passing passengers (persons/hr.)	26,021	41,872	53,012	63,543
	Train consist x number of train/hr.	6x13	9x13	9x17	9x20
Line 2 and Line 5	Passing passengers (persons/hr.)	32,601	51,617	60,009	68,958
	Train consist x number of train/hr.	6x16	9x17	9x19	9x22

Note: Passengers in one car is assumed to be 350.

Table III-4-3 Transportation Plan in Rush Hour (Alternative-B)

Route	Item	1982	1985	1990	1995
Line 1	Passing passengers (persons/hr.)	29,795	46,200	56,120	65,797
	Train consist x number of train/hr.	6x15	9x15	12x14	12x16
Line 3	Passing passengers (persons/hr.)	18,617	28,613	32,434	36,412
	Train consist x number of train/hr.	6x10	6x14	6x16	6x18
Line 4	Passing passengers (persons/hr.)	21,065	33,896	42,914	51,440
	Train consist x number of train/hr.	6x10	6x16	9x14	9x17
Line 2 and Line 5	Passing passengers (persons/hr.	26,391	41,787	48,579	55,823
	Train consist x number of train/hr.	6x13	9x14	9x16	9x18

Note: Passengers in one car is assumed to be 350.

and 73 point on Sunday against 100 points of the weekdays, and it is desirable that the train operation plans will be prepared for weekdays and Sunday respectively (including holidays).

4-1-2 Train Route

Train routes are fundamentally planned to be independent each other without through operation between routes, except Line No. 2 and No. 5 which are planned with through operation.

Although desire of through operation of Line No. 1 and No. 4 was proposed from Mexican side, through operation is not planned for the time being, because the results of passenger flow survey indicated little demand of this through operation at the early stage of the operation.

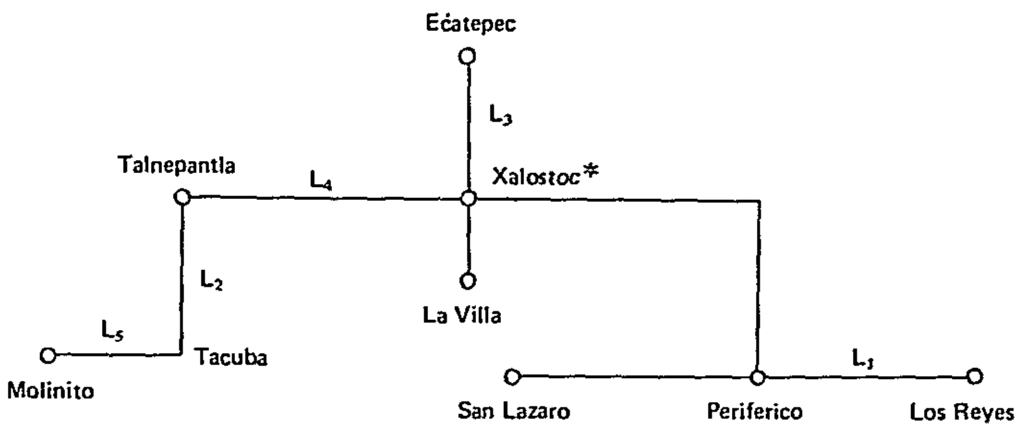
Train routes of each line are as follows :

Line 1:	San Lazaro-Los Reyes
Line 2 and Line 5:	Tlalnepantla-Molinito
Line 3:	La Villa-Ecatepec
Line 4:	Periferico-Tlalnepantla

4-1-3 Drivers' Depot

As a rule, drivers' depot will be established at the terminal of each line. In the following figure o-marks indicate the drivers' depot

* Drivers' Depot will be planned at Xalostoc because a car-depot will be established there.



As for the equipment related to the drivers' operation, ATC and ATO are planned to be applied for the alternative-A, and ATC for the alternative-B, but in both cases train-crew will be one (a driver only) per one train. (refer to paragraph 4-1-4).

4-1-4 ATC and ATO

The ATC system is an equipment to apply brakes automatically in case the actual speed of a train in operation exceeds the permissible speed, and release brakes in case the speed comes down to the permissible speed, and thus train collisions can be prevented by application of ATC, however, stopping train to a pre-determined position of the station is relied on the driver's operation. On the other hand, ATO (Automatic Train Operation) is aimed at the automation of the train operation from the starting to the stopping at the platform, within the permissible speed controlled by ATC. In this case, the major jobs of the driver are to open and close the doors at stopping at the stations, and supervising during the train is running. Although the degree of security in this case is the same as in case ATC only is applied (alternative-B), the addition of ATO (alternative-A) allows reduction of train intervals as well as reduction of training period for drivers or omission of some part of the education can be expected. The related construction cost including on the car and ground equipment, however, becomes higher in comparison with the case of ATC only.

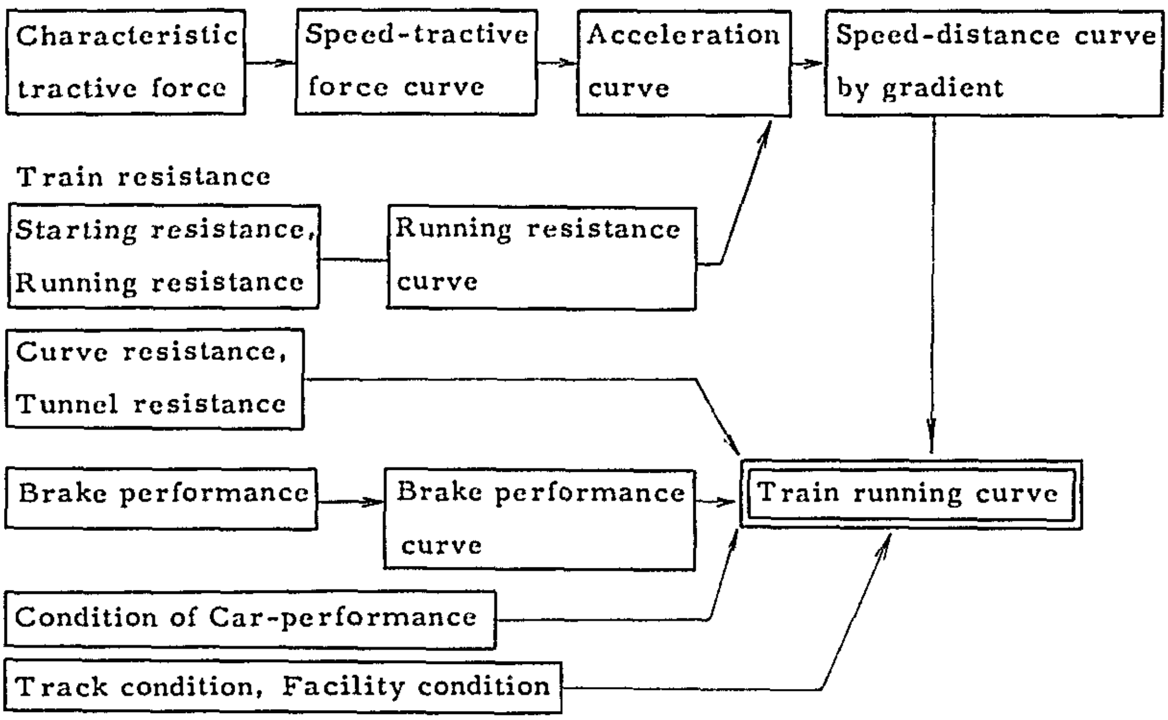
4-2 Train Running Curve and Standard Running Time

4-2-1 Train Running Curve

Train running curve will be the basis for the preparation of train operation plan such as assessment of standard train running time, determination of train operation performance, train control system and interval between trains, etc.

The train running curve shows the operation condition of trains such as interrelation between running speed, running time and running distance. The train running curve will be made on distance base or on time base, and the curve on distance base will be used for the assessment of running time.

Train running curve will be obtained through the following process:



Major values used for this planning are as follows:

(1) Cars

Train consist 4 M 2 T

Note: Almost equal performances are expected for the train consist of 9-cars and 12-cars.

Train weight (For aluminum car body, 350 persons on a car)	376 tons
Mean electric current at accelerating	700 A
Mean acceleration 0 - 40 Km/hr	3. 3 Km/hr/sec
Mean deceleration in stopping at station	3. 0 Km/hr/sec

(2) Speed restriction

In a curved section,

Radious of the curve (m)	300	400	500
Maximum speed (Km/hr)	70	80	90
Turnout, number 12	50 Km/hr		

(3) Planned maximum speed 100 Km/hr

Train running curves prepared under above condition are shown in attached Fig. III-4-1 to Fig. III-4-4.

4-2-2 Standard Running Time

Train diagram will be prepared by the unit of 10 seconds on the basis of described train running curve.

Standard running time for each line is shown in Table III-4-4 to Table III-4-7.

Table III-4-4 Standard Running Time Table Line 1

Down Train	Section		Up Train
Electric railcars	Tractive unit	Distance	Electric railcars
4 M 2 T	Train consist		4 M 2 T
Standard running time (min-sec)	Station		Standard running time (min-sec)
	SAN LAZARO	(Km)	3 - 20
2 - 30	I. ZARAGOZA	2.2	2 - 00
1 - 50	R. CHURUBUSCO	2.0	2 - 20
2 - 20	PERIFERICO	2.7	1 - 50
2 - 00	TELECOMUNICACIONES	1.9	2 - 40
2 - 40	LAS TORRES	2.9	2 - 10
2 - 10	ERMITA ZARAGOZA	2.4	2 - 40
3 - 40	LOS REYES	2.8	
17 - 10	Total	16.9	17 - 00

Table III-4-5 Standard Running Time Table Line 3

Down Train	Section		Up Train
Electric railcars	Tractive unit	Distance	Electric railcars
4 M 2 T	Train consist		4 M 2 T
Standard running time (min-sec)	Station		Standard running time (min-sec)
	LA VILLA	(Km)	3 - 20
2 - 20	CARRERA	1.9	2 - 00
2 - 00	C.T.M.	2.0	1 - 30
1 - 30	XALOSTOC	1.3	2 - 30
2 - 30	RUSTICA	2.5	2 - 00
2 - 00	DIAZ ORDAS	2.1	1 - 50
1 - 50	STA. CLARA	1.8	2 - 10
2 - 10	TULPETLAC	2.3	4 - 20
5 - 10	ECATEPEC	5.0	
19 - 40	Total	18.9	19 - 40

Table III-4-6 Standard Running Time Table

Line 4

Down Train	Station		Up Train
Electric railcars	Tractive unit	Distance	Electric railcars
4 M 2 T	Train consist		4 M 2 T
Standard running time (min-sec)			Standard running time (min-sec)
	PERIFERICO	(Km)	3 - 40
3 - 00	ARENAL	3.0	3 - 00
2 - 50	CUCHILLA DEL TESORO	3.1	2 - 00
2 - 00	ARAGON	2.2	2 - 00
2 - 00	IMPULSORA	2.0	3 - 00
3 - 00	SAN FELIPE	3.5	2 - 00
2 - 10	XALOSTOC	2.3	3 - 30
3 - 30	TICOMAN	4.4	2 - 30
2 - 30	PROGRESO NACIONAL	2.7	2 - 20
2 - 10	TENAYUCA	2.3	2 - 30
3 - 20	TLAINEPANTLA	2.2	
26 - 30	Total	27.7	26 - 30

Table III-4-7 Standard Running Time Table

Line 2 and 5

Down Train	Station		Up Train
Electric railcars	Tractive unit	Distance	Electric railcars
4 M 2 T	Train consist		4 M 2 T
Standard running time (min-sec)	Station		Standard running time (min-sec)
	TLALNEPANTLA	(Km)	3 - 10
2 - 30	VALLE DE MEXICO	2.3	3 - 00
3 - 00	ATZCAPOZALCO	3.6	2 - 10
2 - 10	TACUBA	2.3	(2 - 20)
(2 - 20)	X	(2.5)	(2 - 40)
(3 - 30)	MOLINITO	(2.5)	
13 - 30	Total	13.2	13 - 20

Note: Figures in parentheses are on assumption.

4-3 Train Diagram

4-3-1 Type of Train

As types of trains for suburban railway two types of trains will be considered, one is stopping train which stops at every station and the other is rapid train, which passes some stations. However, this project will be planned to make all the train as stopping trains and un-coupling or coupling of the train consist will not be conducted, because route length is relatively short.

4-3-2 Stopping Time

When 3-platforms are prepared for the stations except for terminal stations (alternative-A), stopping time at an intermediate station will be planned to be 15 sec. and that at a transfer station 25 sec., and in case one platform (alternative-B) will be 20 sec. and 30 sec. respectively.

4-3-2 Time Required

The train diagram will be prepared based on the above described train running time and stopping time. Although, the stopping time for the alternativeA- is 5 sec. shorter than that of alternative-B at each station, stopping time of alternative-B will be employed here. Table III-4-8 indicates the time required for each line.

Table III-4-8 Time Required

Route	Section	Total length (Km)	Mean time required both-ways (min-sec)	Total stopping time (min-sec)	Margin (sec)	Time required (min-sec)	Scheduled speed (Km/hr)
Line 1	San Lazaro-Los Reyes	16.9	17-05	2-10	0-15	19-30	52.0
Line 3	La Villa-Ecatepec	18.9	19-40	2-30	0-20	22-30	50.4
Line 4	Perferico-Tlalnepantla	27.7	26-30	3-10	0-20	30-00	55.4
Line 2 and Line 5	Tlalnepantla-Molinito	13.2	13-25	1-30	0-35	15-30	51.1

4-3-4 Train Diagram

(1) Train schedule time zone

Schedule time of each line will be from 5:00 in the morning to 1:00 of the next day (mid-night).

Time zone of rush hours will be about 6:30 - 9:30, 14:00 - 16:00, 18:30 - 21:00.

Train intervals in the time except for rush hours, will be about the double of the intervals in rush hours.

In the case of Sunday and Holiday, train diagram will be made based on the interval of the time except for rush hours to the whole day.

(2) Number of trains and train kilometers

Number of trains and train kilometers by year and route for alternative-A and alternative-B are shown in Table III-4-9 and Table III-4-10 respectively.

Table III-4-9 Number of trains and train kilometers (Alternative-A, weekday diagram)

Route	Item	1982	1985	1990	1995
Line 1	Number of trains Train-Kms.	324 5,476	486 8,213	432 7,301	514 8,687
Line 3	Number of trains Train-Kms.	324 6,124	460 8,694	514 9,715	406 7,673
Line 4	Number of trains Train-Kms.	352 9,750	352 9,750	460 12,742	540 14,958
Line 2 and Line 5	Number of trains Train-Kms.	432 5,702	460 6,072	514 6,785	594 7,841
Total	Number of trains Train-Kms.	1,432 27,052	1,758 32,729	1,920 36,543	2,054 39,159

Note: Number of trains show that of both ways.

Table III-4-10 Number of trains and train kilometers (alternative-B, weekday diagram)

Route	Item	1982	1985	1990	1995
Line 1	Number of trains Train-Kms.	406 6,861	406 6,861	378 6,388	432 7,301
Line 3	Number of train Train-Kms.	270 5,103	378 7,144	432 8,165	486 9,185
Line 4	Number of train Train-Kms.	270 7,479	432 11,966	378 10,471	460 12,742
Line 2 and Line 5	Number of train Train-Kms.	432 4,646	460 4,990	514 5,702	594 6,415
Total	Number of train Train-Kms.	1,298 24,089	1,594 30,961	1,620 30,726	1,864 35,643

Note: 1) Number of trains show that of both ways.

2) Because of differences of train consist some amount of the alternative-B may become larger than that of alternative-A.

(3) Train diagram

Weekday diagrams in alternative-B at the beginning of the operation are shown in attached Fig. III-4-5 to Fig. III-4-8.

4-4. Number of Cars

Table III-4-11 and Table III-4-12 show the number of cars necessary for the train operation plan by year and route of alternative-A and alternative-B respectively.

Number of cars in service will be calculated on the basis of the scheduled speed and train intervals in rush hour assuming the time to turn back at the terminal station as 5 min.

Number of reserved cars will be calculated on the basis of intervals between inspection which will be described in paragraph 10-1, Inspection System of Cars for the 1982 and 1985 on the basis of inspection intervals for the time being, and for 1990 and later on the basis of future inspection intervals.

Table III-4-11 Number of Cars (alternative-A)

Route	Number of Cars	1982	1985	1990	1995
Line 1	In service	9x10	9x15	12x13	12x16
	Reserve	15	18	18	21
	Total	105	153	174	213
Line 3	In service	6x11	6x17	6x18	9x14
	Reserve	12	12	12	15
	Total	78	114	120	141
Line 4	In service	6x16	9x16	9x20	9x24
	Reserve	12	18	18	24
	Total	108	162	198	240
Line 2 and Line 5	In service	6x11	9x12	9x13	9x15
	Reserve	12	15	12	15
	Total	78	123	129	150
Total	In service	318	489	561	669
	Reserve	51	63	60	75
	Total	369	552	621	744

Table III-4-12 Number of Cars (alternative-B)

Route	Number of Cars	1982	1985	1990	1995
Line 1	In service	6x13	9x13	12x12	12x13
	Reserve	12	18	15	18
	Total	90	135	159	174
Line 3	In service	6x10	6x13	6x15	6x17
	Reserve	12	12	12	12
	Total	72	90	102	114
Line 4	In service	6x12	6x19	9x17	9x20
	Reserve	12	15	18	18
	Total	84	129	171	198
Line 2 and Line 5	In service	6x10	9x10	9x11	9x13
	Reserve	12	15	12	12
	Total	72	105	111	129
Total	In service	270	399	426	555
	Reserve	48	60	57	60
	Total	318	459	543	615

5. Railway Facilities

5-1. Construction Standards

5-1-1. Curve

Radius of curved track shall be larger than the following:

Main line track	400 m (300 m)
Within or Nearby turnout in Main track	320 m (160 m)
Parts along with platform except both ends	600 m (500 m)

The figures in ( ) are permissible when circumstance such as track conditions compels to do so.

This minimum radius shall be used only in an unavoidable case, and in general the radius of the curve should be selected as large as possible so that the limitation of speed and the track maintenance efforts will be lessened.

5-1-2. Gradient

The gradient shall be more gentle than the limit value shown below:

Main line	30 ‰
In a station yard (between the remotest turnouts)	3.5 ‰

The limit is exempted on the line where vehicles are not released or coupled, and as far as the gradient will not cause any difficulty to the departure and arrival of trains.

5-1-3. Construction Gauge.

(1) Construction gauge in straight track shall be as shown in the drawing III-5-1.

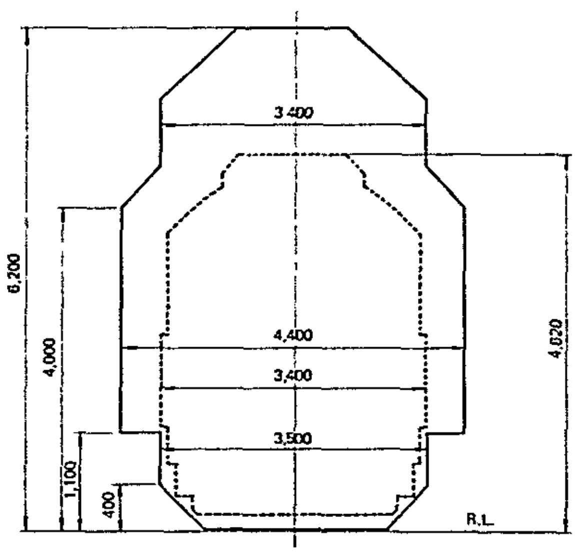


Fig. III-5-1 Construction Gauge

Note: ——— is construction gauge for general case. Gauges for tunnels, bridges, sheds on platforms, platforms, etc., can be reduced from the general construction gauge.
- - - - is clearance limit for rolling stock.

(2) Extension of construction gauge on the curved track with the radius not larger than 2, 000 m shall be in accordance with the increment as shown in the following equation:

$$w=39,000/R \text{ (mm)}$$

where,

w ; Value of increment to the each side of the track center line (mm)

R ; Radius of the curvature (m)

length of the vehicle	L=24.5 m
distance between the bogie center	a =17.5 m
rigid wheelbase	l =2.3 m

$$w_1 = \frac{39,000}{R} \text{ (mm)}$$

$$w_0 = \frac{36,000}{R} \text{(mm)}$$

in this case $w_1 > w_0$, then the increment will be w_1.

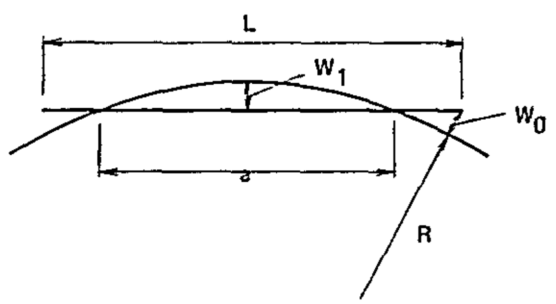


Fig. III-5-2 Increment of construction gauge

5-1-4. Cant

Following cant shall be given to the curve:

$$C = 11.8\frac{V^2}{R}$$

where : V, Train speed (Km/hr)

R, Radius of curvature (m)

Maximum cant shall be limited to 150 mm in consideration of the uncomfortableness of the passenger and the safety of the car against overturning, when the car stopped in the curve.

Maximum cant deficiency shall also be limited within 60 mm in consideration of the safety of the car and the uncomfortableness of passengers, when the car is passing through.

Table III-5-1 indicates the relations among radius of curvature, allowable maximum speed and cants.

Table III-5-1 Curve and Cant

Radius m	Max. Permissible speed Km/hr.	Actual Cant mm	Deficiency of Cant mm
300	70	150	60
400	80	150	60
500	90	150	60
600	100	150	60
700	110	150	54
800	110	150	28
900	110	150	9
1000	110	143	0
1500	110	95	0
2000	110	71	0

5-1-5. Slack

An optimum amount of slack shall be given to the curved track of the radius less than a given value, based on the value obtained by the following equations:

$$S = \frac{1}{2}(S_1 + S_2)$$

$$S_1 = 281\frac{\ell^2}{R} - \frac{P}{2}$$

$$S_2 = 250\frac{\ell^2}{R} - P$$

where,

S ; Slack (mm),

S_1 ; Slack determined by the conditions of easy passing (mm),

S_2 ; Slack determined by the conditions of difficult passing (mm),

ℓ ; Rigid wheelbase (m)

R ; Radius of curvature (m),

P ; Play (difference between track gauge and wheel back gauge) (mm)

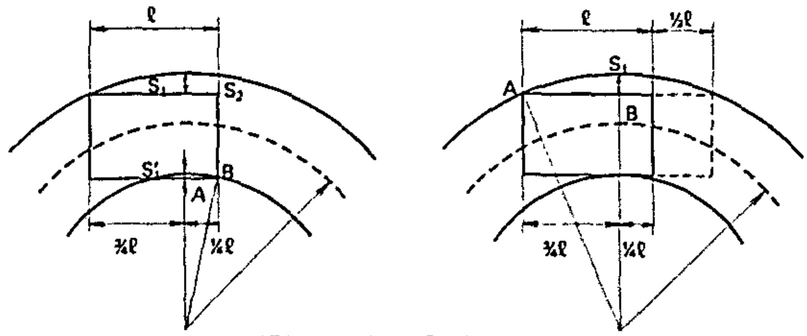


Fig. III-5-3 Slack

5-1-6. Transition curve

(1) The length of the transition curve shall be more than the largest value calculated by the following equations:

$L_1 = 0.8\ Cm$

$L_2 = 0.0075\ CmV$

$L_3 = 0.0062\ CdV$

where;

L_1, L_2, L_3 ; Length of the transition curve (m),

Cm ; Actual cant (mm),

Cd ; Deficiency of cant (mm),

V ; Maximum train velocity (Km/hr)

where L_1 indicates the limit of safety against derailment by three point suspension of the bogie, L_2 indicates the allowable limit of riding comfortableness to the rate of cant changes in terms of time. While, L_3 indicates the allowable limit of the riding comfortableness to the rate of changes of unbalanced centrifugal force in terms of time.

(2) Feature of the transition curve shall be three dimentional parabolical.

5-1-7. Straight Line Inserted Between Curves, Minimum Curve Length

(1) More than 30 m of straight line shall be inserted between the two adjacent transition curves, to avoid the increase of lateral vibration of a car.

(2) The length of the circular curve shall be more than 30 m.

5-1-8. Vertical Curve

Where gradient changes, vertical curve of the radius larger than that shown below shall be inserted for keeping comfortability and safety against rising of the car body by force exerted from the front and back cars:

For the curve of radius less than 800 m;	4, 000 m
For the other case	3, 000 m

5-1-9. Distance Between Track Centers

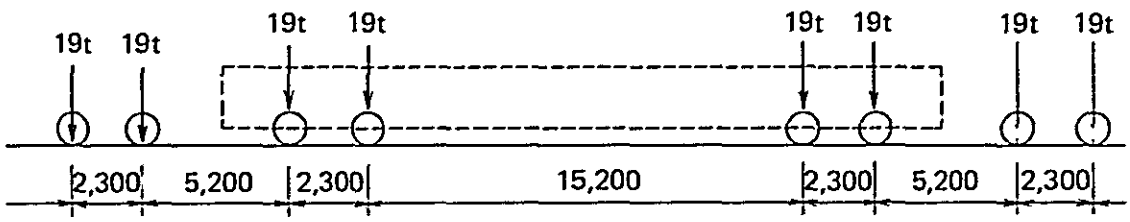
Distance between track centers shall be more than 4. 20 m at outside of station yard. The distance, however, can be reduced to 4. 0 m in inevitable cases.

In the station yard, the center distance between the parallel tracks shall be more than 4. 40 m. However, the distance can be reduced to 4. 2 m in the place where the same space is not required for working in the yard.

Distance between track centers in curved line shall be increased more than twice that of construction gauge increments shown in paragraph 5-1-3.

5-1-10. Design Load

This railway is to be used solely for passenger transportation. Consequently the design load of the structure is recommended to be determined by adding about 2 tons to the actual axle load of the electric car in consideration of the effect of the repeated load. The weight distribution is shown in the drawing III-5-4.



(Note) Loaded length shall be longest train length.

Fig. III-5-4 Design Live Load

5-1-11. Condition of Combination Factors

Standard for the case of each combination of factors shall be as shown in the table III-5-2.

(1) *Turnouts and gradient*

When a turnout is constructed in steep slope section, maintenance becomes very difficult because of creeping, etc. As a rule, turnouts shall not be constructed to the place steeper than 3. 5 ‰ (Limit of gradient in a station yard).

Table III-5-2 Conditions of Combination Factors

Turnout	NO Use special design for an indispensable case (2)	NO (3)	OK with ballast		
Expansion Joint	OK for R=600 m or more	NO (5)	OK		
Gradient	OK	OK	OK	OK For 3. 5 % or less (1)	
Vertical Curve	r = 4, 000 m for R ≦ 800 m r = 3, 000 m for R > 800 m	NO (4)	NO (6)	NO (3)	NO (5)
	Circular Curve	Transition Curve	Bridge	Turnout	Expansion Joint

(2) Turnouts and circular curve

In general, insertion of turnout in circular curve should be avoided from the view point of train operation safety and maintenance.

(3) Turnout, transition curve and vertical curve

Turnouts have complicated structure including small radius lead curve or recessed parts for crossing. Therefore, turnouts shall not be inserted into the transition curve or vertical curve because of train operation safety.

(4) Transition curve and vertical curve

Transition curve and vertical curve have unfavorable factors respectively for operation security and passenger's riding quality. From this reason, combining these two curves on the same section is not allowed.

(5) Expansion joints and transition curve and vertical curve

Design, manufacture and maintenance of expansion joints in a transition curve are very difficult because the curvature and cants are changing throughout the curve.

(6) Vertical curve and bridges

Vertical curve should not be applied to bridges because the fracture angle arised at an abutment or a pier may superpose upon vertical curve resulting in the problem of uncomfortableness.

5-2. Longitudinal Alignment

This railway is planned basically to run on the ground surface making grade separation with main roads, to leave no level crossing. Selection of crossing system may cause severe rise and fall of the route, and may effect the cost and term of construction. Consequently following facts should be regarded for the planning:

5-2-1. Matters to be Considered

(1) The longitudinal alignment of a railway shall be as straight as possible.

(2) Number of grade separation shall be minimized to the possible extent by the rearrangement of roads with the construction of side paths (Fig. III-5-5).

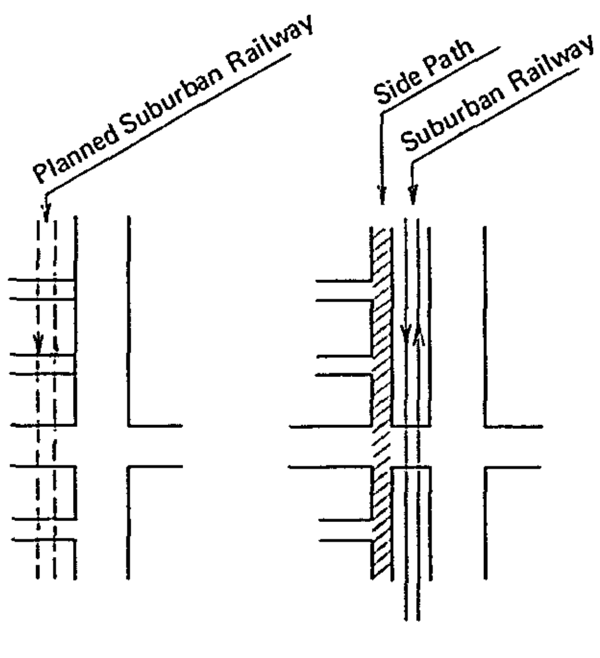
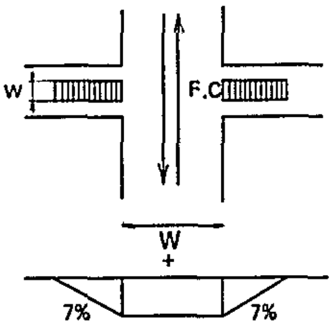
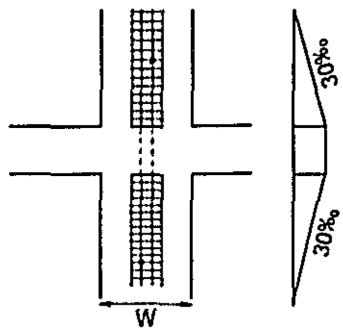


Fig. III-5-5 Decrease of Number of Grade Separations

(3) As the form of grade separation, preferably the road will be adjusted up or down as far as agreeable with road -authority from the view point of above (1) (Table III-5-3).

Table III-5-3 Types of Grade Separation

Types / Items	Road Under-passing Type	Railway Under-passing Type
Sketches of Crossing		
Problems from the system	* Left turn impossible. * This type is not applicable for complicate crossing such as three folked crossing. * Effect of road style change to the roadside residents shall be considered.	* Little effects to the road. * Sometimes may cause loss gradient to railway side.
Construction cost (see Note)	When the width of road (W, w) is small, this type is advantageous	When the width of the road (W, w) is large, this type is advantageous.
Problems on construction	Difficulties is expected by limitting of road traffic during construction.	Little effects to the road traffic during the construction.

Note: Careful study for the assessment of construction cost is essential, considering the difficulty of the work.

(4) System of continuous elevated railway shall be examined if it is permissible under the geological condition, because the system is seemed sometimes advantageous from the points of longitudinal alignment and of reducing construction costs.

(5) A longitudinal alignment by which the railway goes underground deeper than needed shall be avoided, considering to shift exsisting under ground crossing road or other burried matters.

(6) Avoid loss gradient (conditions require braking in downgrade) as much as possible, which may cause energy loss.

(7) Stations are desirable to be constructed on the ground for the reason to decrease construction cost as well as related with the condition of the paragraph (6). Fig. III-5-6, is an example of grade separation crossing with the railway going underground. Although the longitudinal configuration is not good, the train starting A-station is accelerated by the down-hill slope and decelerated by the up-hill slope as it nears the B-station resulting in no energy loss. In the reverse case, if the B-station is located in a valley portion, excess energy is required by braking on downward slope and accelerating against upward slope.

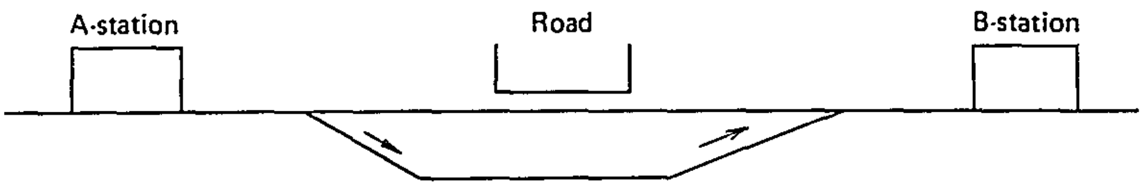


Fig. III-5-6 Grade Separation and the position of stations

(8) Complete adjustment shall be made with the urban planning, considering the future development of the city.

5-2-2. Longitudinal Section

App.-Fig. III-5-1, App. III-5-2, App. III-5-3 and App. III-5-4 are the modified drawing of Mexican basic plan in consideration of above described condition as well as geological and topographical conditions.

The common points of modification to each line are making station yard (between turnouts at both ends) flat as well as making modification required from combination factors described in paragraph 5-1-11.

Other major points of modification are as following:

(1) Elevated road style is recommended for the grade separation crossing with the Sidar Street in consideration of the necessity to make 1,300 m long level section in San Lazaro Station on route No. 1 and of the

interference with underground-crossing road of the Moctezuma Station of the subway.

(2) A continuous elevated railway is considered to be adequate in the vicinity of Tacuba Station for the reasons of connection between line No. 2 and No. 5 and topographical conditions.

(3) The Tlalnepantla Station on route No. 2 and No. 4 is preferable to be built on surface considering the relations with Rio de los Remedios flowing near by, and the reduction of construction cost.

(4) Carrera Station on route No. 3 is considered better to be on surface from the view point of reducing construction cost.

(5) Route No. 4 has surface grade separations (elevated railway) because the route approaches water-way in many places, and the problem of water leakage is serious in such places.

(6) The crossing of route No. 4 with Av Texcoco was decided to be grade separation from the amount of road traffic.

Of course it is necessary to study the adequency or adaptability of above modification from other view points and the final decision should be made based on the general evaluation,

Improvement of longitudinal alignment after starting operation is quite difficult. Consequently it is essential to make up the best plan by synthesizing the whole situation, based on the described conditions and, at the same time, with full consultation with city authorities.

5-3. Roadbed

5-3-1. Roadway Diagraph

The roadway diagraph is shown in the Fig. III-5-7. Breadth of the formation level from the track center to the outside edge (excluding gutters) was taken more than 3.54 m to one side and 3.04 m to the other side by securing maintenance path of 1.00 m to one side and 0.50 m to the other side, in consideration of mechanized maintenance work and high speed operation of the train.

5-3-2. Considerations for Execution of Roadbed Work

On the execution of roadbed work, following points should be marked in consideration of geological conditions:

(1) Poor soil of the upper roadbed shall be replaced with good materials as necessary to prevent the mud pumping and the sinking of ballast, and

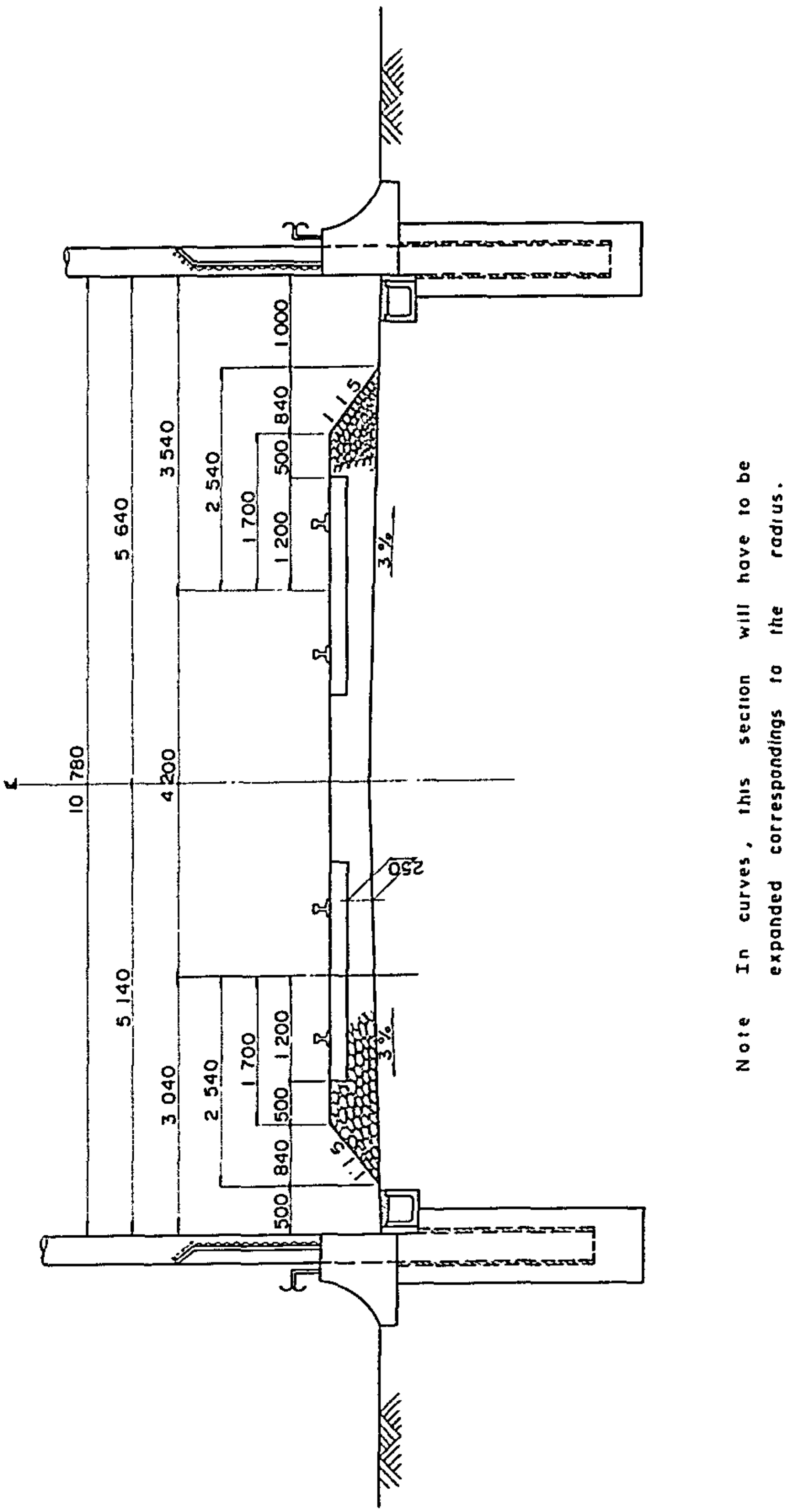
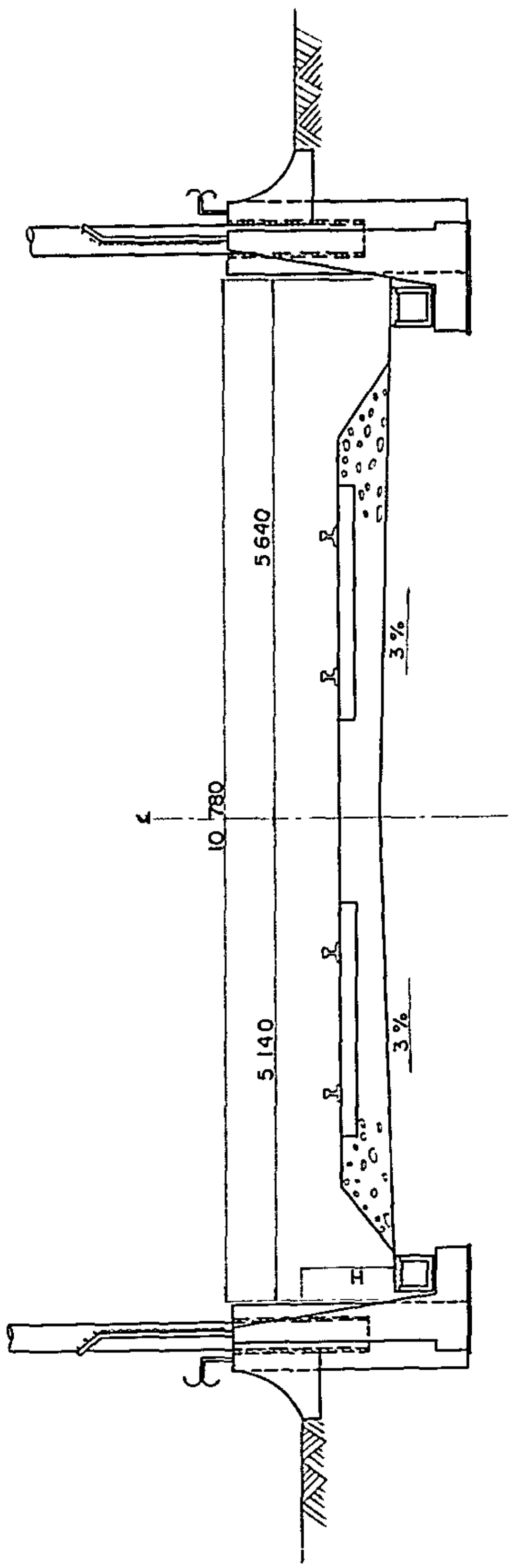


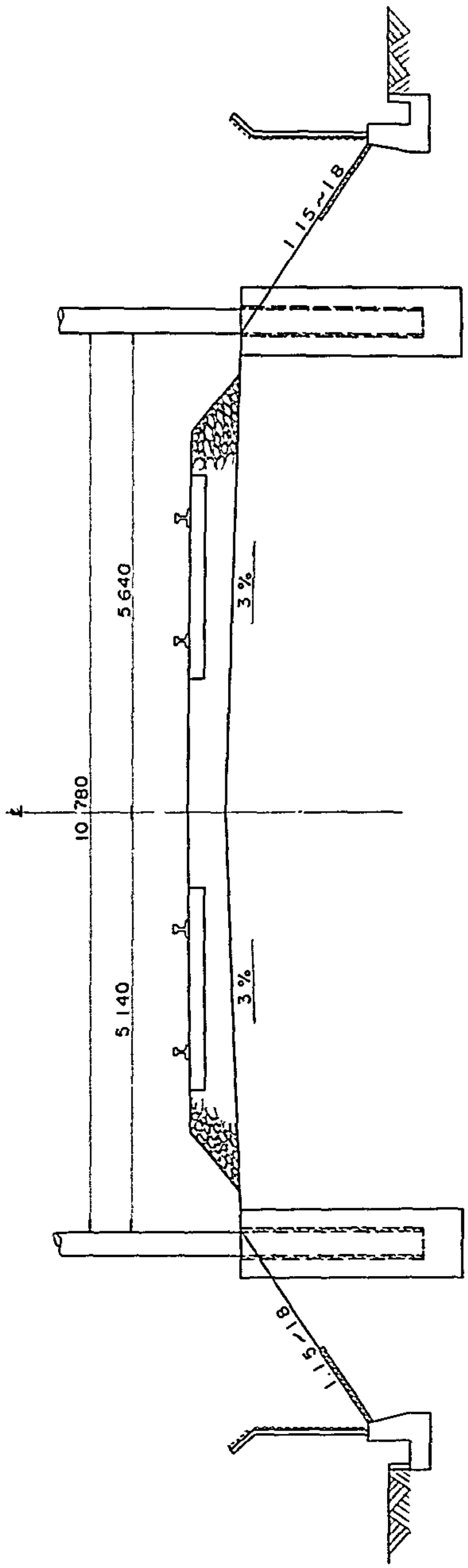
Fig. III-5-7 (a) Typical Cross Section of Level Ground (Unit: mm)



Note. 1 In curves, this section will have to be expanded correspondings to the radius.

2 The design of the retaining walls will have to be adjusted to the depth of the cuts and the condition of the soils.

Fig. III-5-7 (b) Typical Cross Section of Cuts (Unit: mm)



Note . 1 In curves, this section will have to be expanded Correspondings to the radius.

2 The gradient of slopes will have to be adjusted to the soil Conditions.

3 For certain soils and slopes it may be necessary to provide special protections.

Fig. III-5-7 (c) Typical Cross Section of Embankment (Unit: mm) then sufficient tamping shall be applied.

(2) Sufficient drainage shall be prepared so that the strength of the roadbed will not be injured by rise-up of ground-water and accumulation of rain water.

(3) In constructing roadbed on a soft ground, sufficient study shall be carried out on the stabilization and sinking of roadbed and sufficient counter measures shall be taken so that no hindrance may occur after commercial operation is commenced.

(4) Against inevitable residual sinking after entering in operation, counter measures for the future necessity such as to prepare some margin to the breadth of formation level for the estimated slope-face shrinkage shall be taken.

(5) At the terminal side of the route No. 4 where the railway is to be constructed on a water-way bed, various forms of coexistence of railway and water-way can be considered. It is important to decide the best style after sufficient discussion and study with the related organizations so that to leave no problems both from structural and maintenance point of view.

5-3-3. Counter Measure to Soft Ground

Following are the typical examples of countermeasure works to soft ground which have been widely applied in Japan:

(1) Counter weight bank method

The method is to bank at the foot of the slope of mainbank to prevent its sliding destruction caused by insufficient bearing capacity of the subsoil, for the purpose of increasing resistance to sliding (Fig. III-5-8).

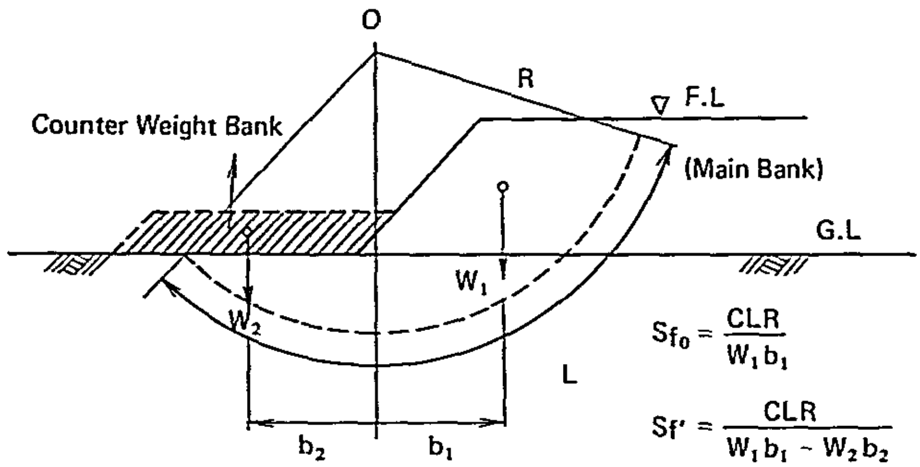


Fig. III-5-8 Counter Weight Bank Method

(2) Partial replacement method

This is the means to increase the shearing resistance of the subsoil or to prevent the sliding failure of bank by replacing poor subsoil with good material. However, replacing down to deep-seated layer is not adequate because of higher cost and long construction term for obtaining and transporting good material, digging out and transporting poor soil (Fig. III-5-9).

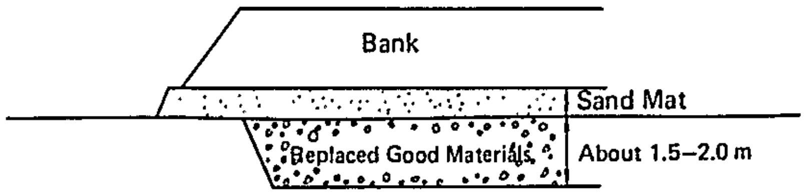


Fig. III-5-9 Partial Replacement Method

(3) Subsoil Reinforcing Method

The method is to improve upper part of subsoil, for example, by driving sand compaction piles or lime piles into the subsoil to increase strength or decrease settlement of the subsoil. Other various measures are available in this method. (Fig. III-5-10).

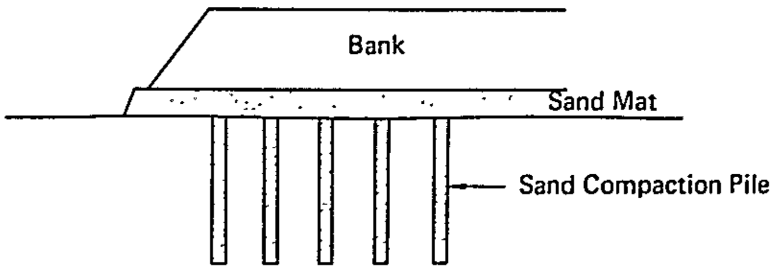


Fig. III-5-10 Subsoil Reinforcing Method

(4) Preloading method

The method is to apply a surcharge load previously to the ground where bank or construction of structure are planned to accelerate the settlement, and then build planned structure and thus reduce its settlement (Fig. III-5-11).

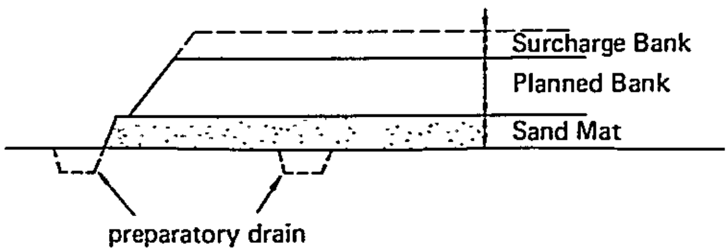


Fig. III-5-11 Preloading Method

(5) Sand drain method

The method is to drive-in sand piles into the soft ground to reduce drain distance of consolidation, expedite settlement due to consolidation and also increase the soil strength.

In many cases, some methods stated above are jointly applied judging from ground conditions, construction conditions, effects to the surroundings, etc.

5-4. Structures of Grade Separation

5-4-1. *Styles of Grade Separation*

In this railway planning, grade separation structures are the most important structures between stations. Both surface and under ground crossing can be considered and the difference of whether the rail or the road will be elevated or lowered leads to various types of crossing. Fig. III-5-12, III-5-13, III-5-14, Photographs show their general idea.

5-4-2. Considerations on the Planning

The structures are large in size and many in number and have large effects on the cost and term for construction.

Consequently selection of the best style based on the study of cost estimation and difficulty of construction is essential as well as considering the following factors:

(1) Requirement from longitudinal alignment.

(2) Adjustment with urban planning.

(3) Topographical and geological conditions.

a) Structural types which may cause maintenance problems shall be avoided. (for example, under ground structure where water-ways are running parallel to the railway may cause water leakage).

b) Generally speaking, under ground crossing is preferable for soft ground from the view point of settlement counter measure.

c) It is a known characteristic of Mexican clay to swell-up by removing a certain load. Consequently the structure shall be rigid one-body structure corresponding to the removed amount of soil in making design.

d) In the case of surface grade separation crossing, special care should be paid not to yield detrimental settlement of the structure or surrounding ground after its completion.

e) It is also essential to take necessary measures to avoid differential settlement between the structure and roadbed before and behind the structure.

(4) Considerations for the beauty of the city.

(5) Considerations for the preservation of the environment.

5-5. Track

5-5-1. Structure of the Track

The railway is planned on the estimation of maximum axle-load of 17 tons and the total passing tonnage of 70 million tons per year. (route No. 1 in 1995). In consideration of such large quantity of transportation, fully strong track structure is preferable.

(1) Rail

Rail of about 60 Kg/m is recommendable. A heavier one of 68 Kg/m (136 lbs/yda) is also acceptable. For the curve of the radius of 600 m (G = 1°55') or less, heat treated rails are recommendable to bear the abrasion.

(2) Sleeper

The arrangement of about 43 P. C. -concrete sleepers per 25 m is recommended. Although Mexican side insists the use of wooden sleeper for noise problem, following advantages of P. C. -sleeper shall be considered:

a) Maintenance job can be reduced for about 15%, because the track becomes stable and replacement of the sleeper is not required.

b) Stability against buckling is obtained in the case of long-rail track.

c) Noise level is considered to be the same with wooden-sleeper because of smooth running of rolling stock on the stable track.

(3) Rail fastening devices

The fastening device shall be of double elastic fastening to increase creep resistance of rail and rail supporting spring constant of soft one to improve the running performance of rolling stock.

(4) Ballast

The ballast shall be of crushed stone and the minimum thickness of ballast under the sleeper shall be about 250 mm right beneath the rail position. The crushed stone should be fully controlled by grain size, grading form and physical properties.

The breadth of balast shoulder outside of the sleeper shall be about 500 mm to be sufficient for the buckling resistance of long welded rail.

(5) Long Welded rail

The long welded rail is recommended for use in the curve radius of 600 m (G = 1°55') or more. The rail is welded to the length of 100 to 200 200 m by flush-butt or gas pressure welding in depot, and to the desired length by aluminothermy or gas pressure welding on the spot. Expansion-joints shall be used to the ends of the long welded rail.

(6) Turnout

The turnout of the main line shall be of number 12 turnout, and is preferable to be of manganese steel crossing.

5-5-2. Maintenance of Track

Maintenance work shall be performed during the time zone of from the last train to the first train, because day-time maintenance is difficult from the density of traffics. Therefore, periodical repair system by machine is recommended. The maintenance system for long welded rail track with PC-sleeper usually does not apply the track renewal system, but mainly relies on periodical exchange of material and tamping of ballast.

The repair work will be classified into the following three:

(1) A-repair

Over all tamping of ballast is executed once in every two years. Deteriorated materials are replaced simultaneously.

(2) B-repair

This repair work is executed at each 6 month interval between the A-repairs, and tamp mainly the section where relatively large irregularities are found by track-inspection car. Other than above, occasional adjustment of joint clearance or replacement of deteriorated materials are performed.

(3) C-repair

Adjustment of large irregularities of track found by track-inspection car, or other repairs, whenever and wherever, are carried out.

As the maintenance standard based on the above works, Table III-5-4 is a recommendable example.

The allowable limit of irregularity of track depends on the performance of rolling stock. Therefore, it is preferable to re-examine the limit by measur-

Table III-5-4 Track Maintenance Standard

(in mm.)

Irregularity	B-repair	C-repair	Finish
Track Gauge	+10 (+6) -5 (-4)	*20 (14) **15 (9)	(+1) (-3)
Level	11 (7)	-	(4)
Longitudinal level	13 (7)	23 (15)	(4)
Alignment	13 (7)	23 (15)	(4)
Twist	-	23 (18)	(4)

Note: 1. Values in ( ) indicate the measurement of static track irregularity.

2. Values without ( ) indicate the measurement by a track inspection car.

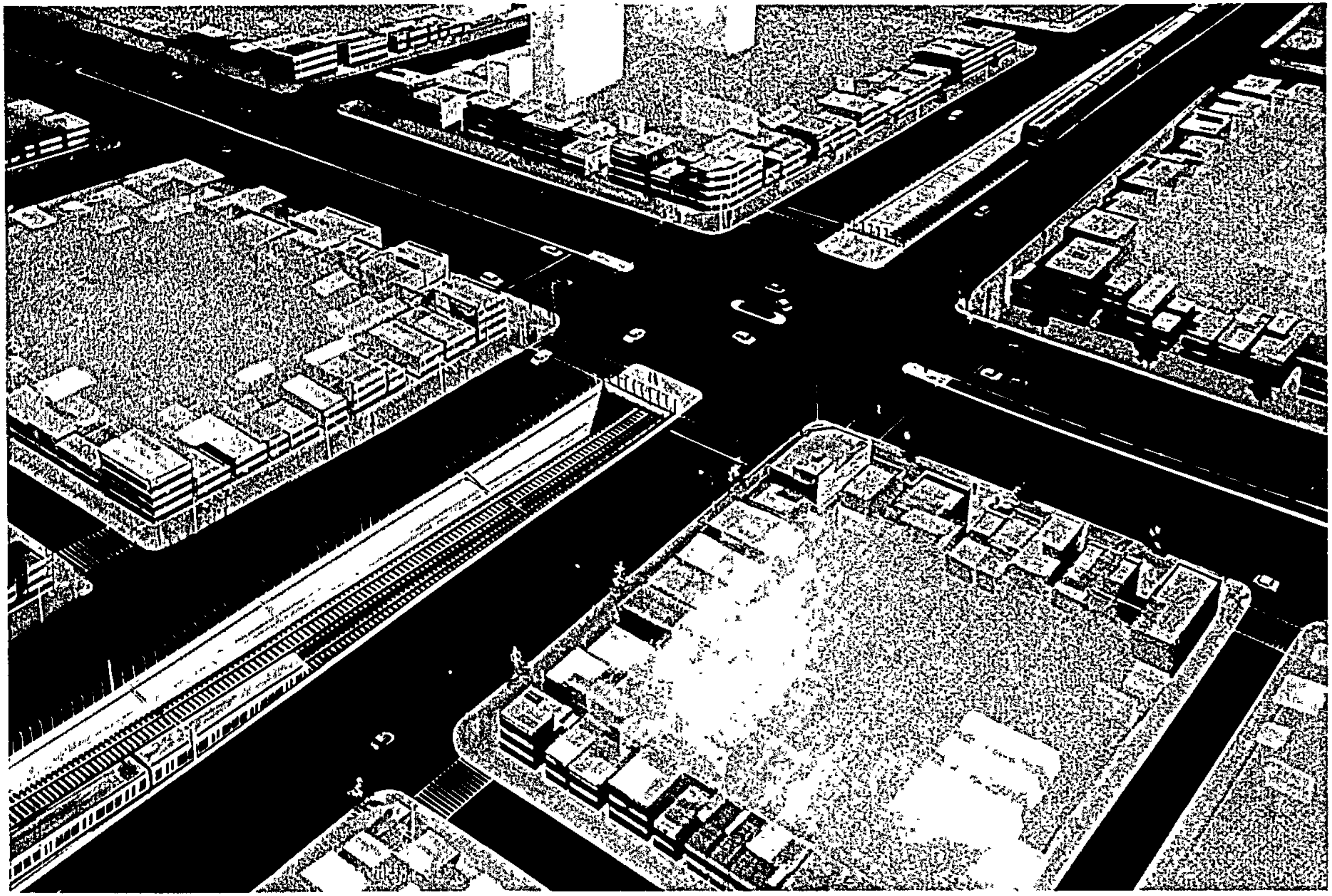
3. Figures in the columns of longitudinal level and alignment indicate the versine for 10m chord.

4. Twist is for 5-m. length.

5. Figure attached with * is for straight track or the section of the slack of 20 mm. or less and ** is for the section of slack of 25 mm or over.

ing irregularity of track, vibration acceleration of the train by test-run after completion of the track.

As the system of maintenance, it is recommendable to organize and classify the maintenance work members into two groups, the one is the working group which mainly conduct periodic repair works and the other is the inspection group which mainly conduct track condition check-up by patrol.



Grade Separated Crossing (Railway Crossing under the Ground)

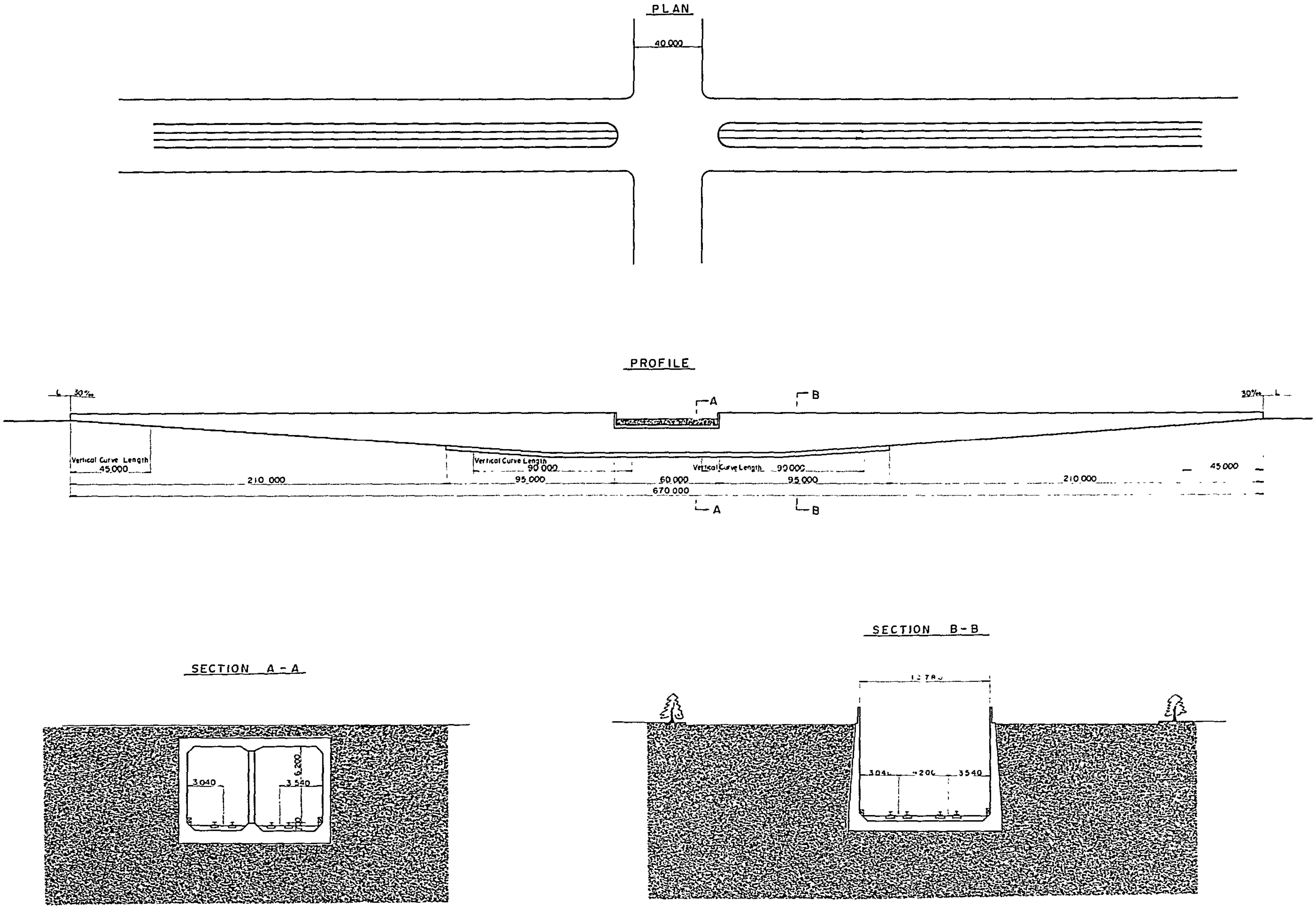
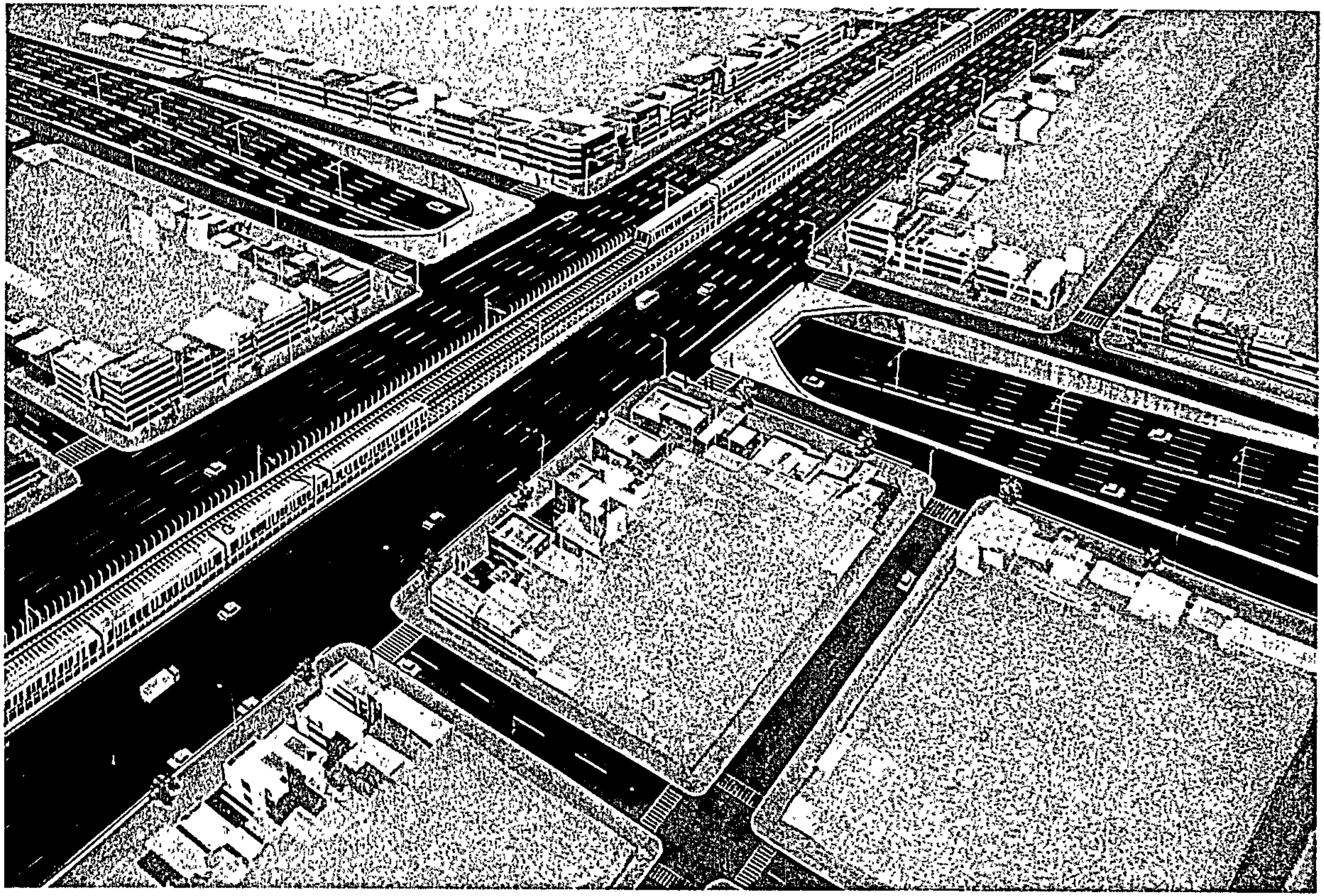


Fig. III-5-12 Grade Separated Crossing (Railway Crossing Under the Ground) Unit: mm



Grade Separated Crossing((Road Crossing Under the Ground)

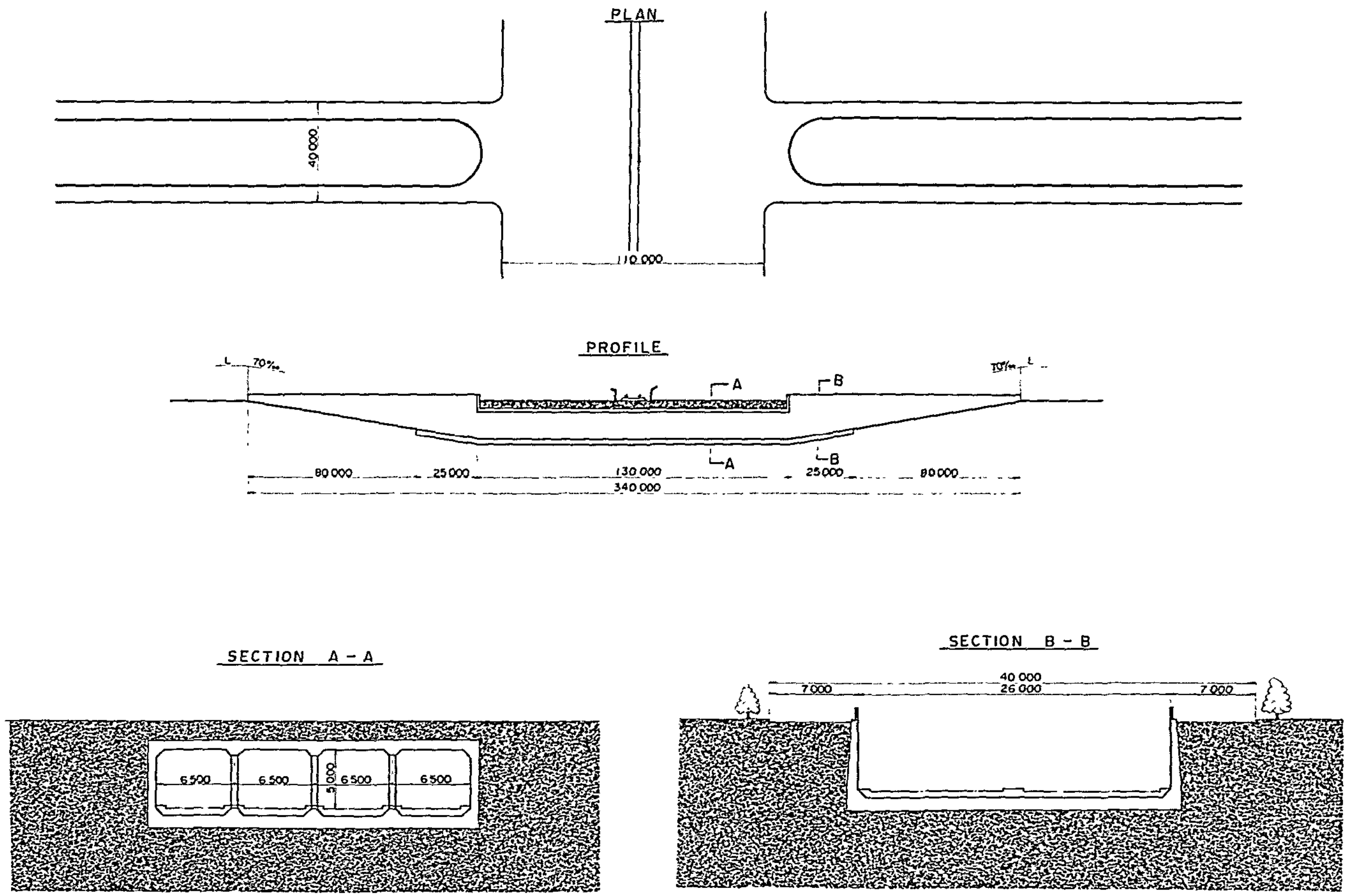
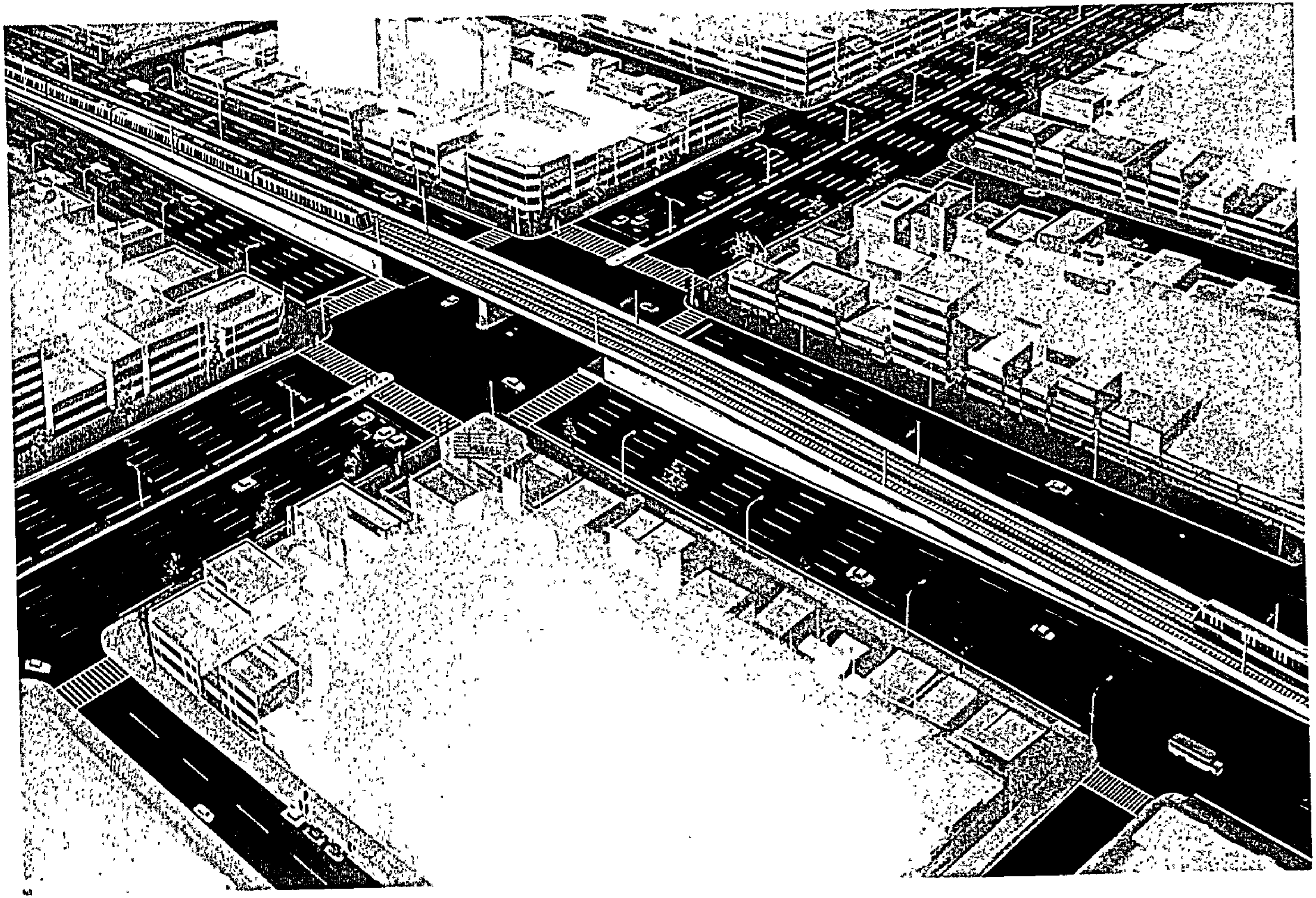


Fig. III-5-13 Grade Separated Crossing (Road Crossing Under the Ground) Unit: mm



Grade Separated Crossing (Railway Crossing Over Road)

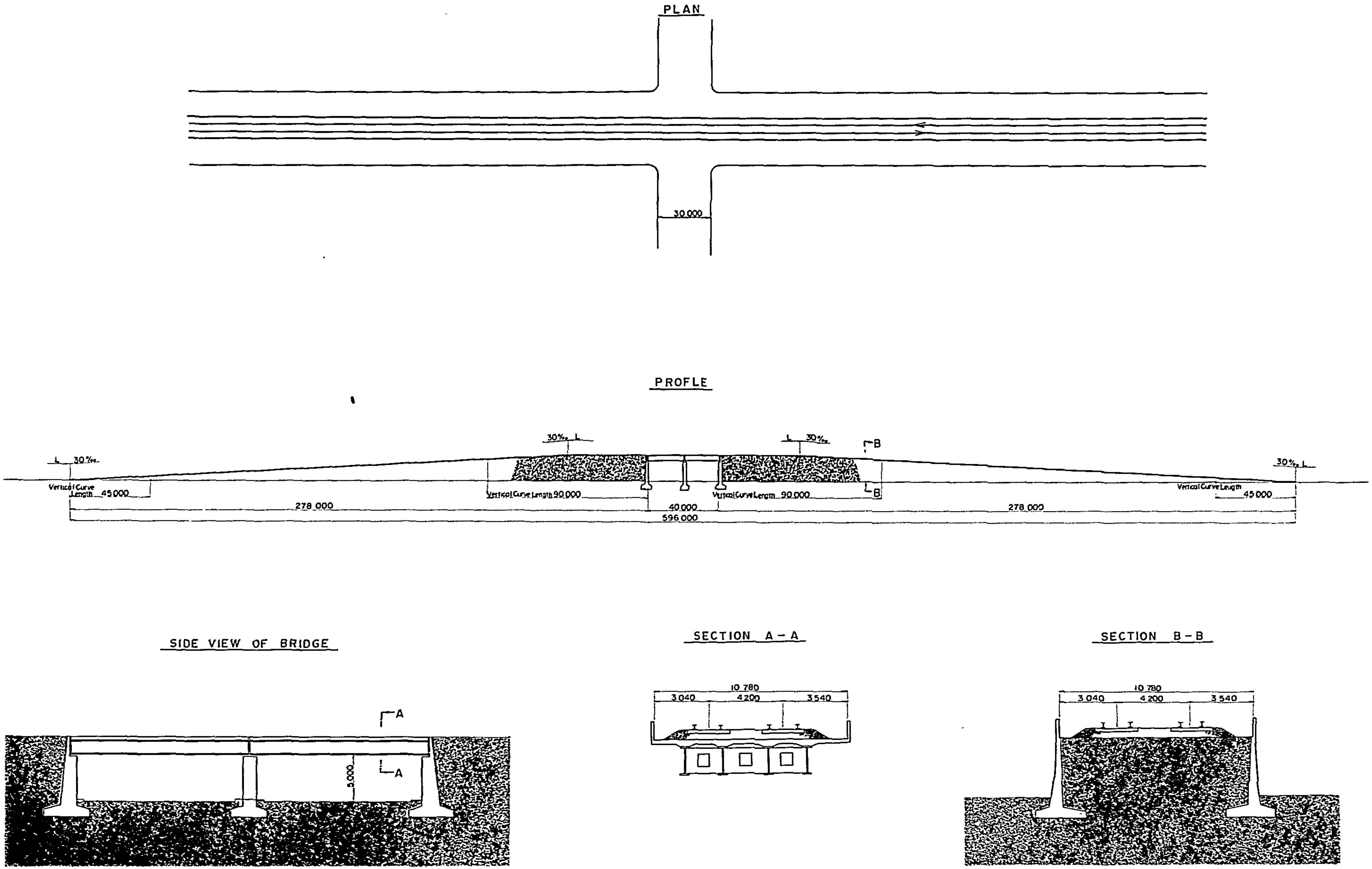


Fig. III-5-14 Grade Separated Crossing (Railway Crossing Over Road) Unit: mm

6. Facilities at Stations

6-1 Layout of Stations

The whole track layout of the Alternative-A and B are shown in App. Fig. III-6-1 and App. Fig. III-6-2.

The arrangements for the terminal and intermediate stations are as described in the following:

6-1-1 Terminal Station

Standard arrangements of terminal station shall be of 5-platform and 4-track system (Alternative-A) or of 3-platform and 4 track system (Alternative-B). (Fig. III-6-1, Fig. III-6-2).

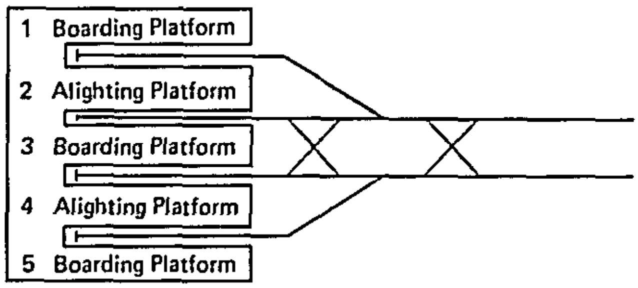


Fig. III-6-1 Terminal Station (Alternative-A)

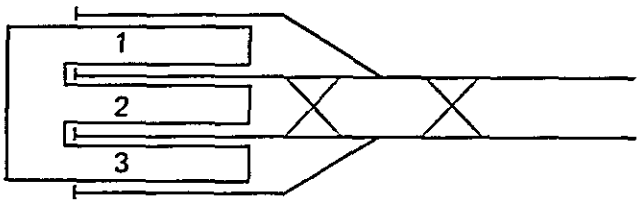


Fig. III-6-2 Terminal Station (Alternative-B)

In the 5-platform and 4-track system, perfect separation of boarding and alighting is possible. In the 3-platform and 4-track system, both outer side platforms must be used for boarding and alighting, although, the central platform can be used solely for boarding.

Both alternative have common drawback that arriving and departing trains cross each other at the entrance of terminal station when the minimum train interval becomes 2 minute or less in future. But this problem can be solved rather easily by preparing draw-out tracks to the back side of the station.

This partly depends on passengers' alighting and boarding time. However, for the stations such as San Lazaro, La Villa, etc., where draw-out tracks are difficult to install from the conditions of location, double turn back system can be considered at the intermediate station (immediately before the terminal station). (Fig. III-6-3).

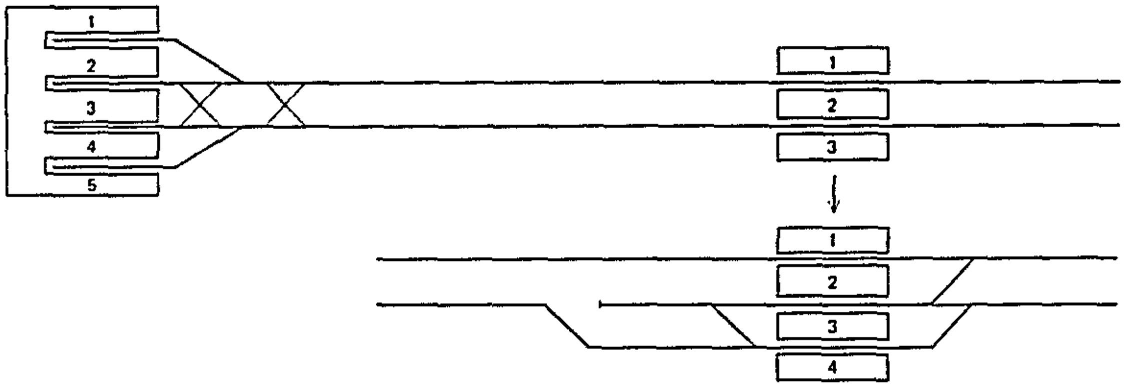


Fig. III-6-3 A Proposal to Increase Train-turn-back Capacity at a Terminal Station

An example of line arrangement applied for No. 1 Line is shown in the Fig. III-6-4.

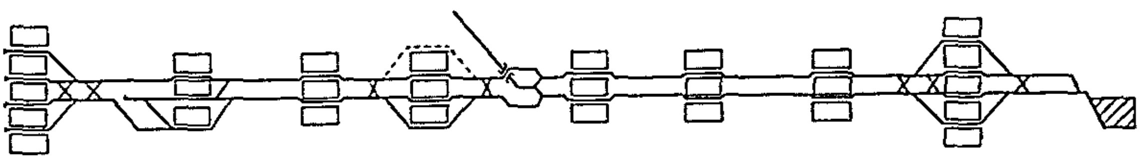


Fig. III-6-4 A Plan for Future No. 1 Route Arrangement

One platform and one track will be increased to I. Zaragoza Station, an intermediate station before San Lazaro, to turn back half of the trains there to help the shuttling of trains at San Lazaro Station.

Thus, trains operated on the main line are turned back alternately at both I. Zaragoza and San Lazaro stations and the turning-back capacity of the line is increased.

Because both I. Zaragoza and San Lazaro stations have good connections with the subway, it is expected that the passengers evenly transfer to all cars at both stations.

While trains can be turned back at both stations during rush hours in order to minimize train interval, all trains can be turned back only at San Lazaro Station during other time of day because operation intervals become longer.

At another terminal station, Los Reyes, turning back of trains during rush hours is possible by drawing out all trains utilizing the shunting tracks of electric railcar depot.

6-1-2 Intermediate Station

Standard arrangements of an intermediate station shall be 3-platform and 2-track system (Alternative-A) or 1-platform and 2-track system (Alternative-B). (Fig. III-6-5 or Fig. III-6-6).

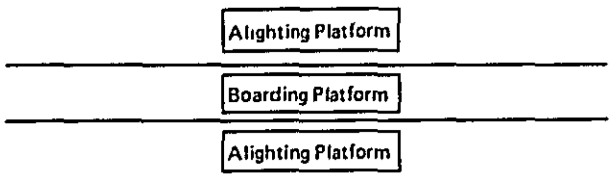


Fig. III-6-5 Intermediate Station (Alternative-A)

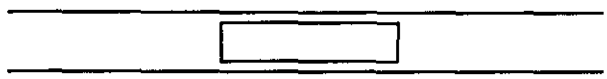


Fig. III-6-6 Intermediate Station (Alternative-B)

Preparation of turnout at the both ends of a platform for emergency turning back or for passing is considered necessary only for several stations judging from its necessity, increase of construction and maintenance costs and speed-limit.

6-2 Platform and Passage

6-2-1 Terminal Station

(1) Alternative-A (5-platform and 4-track system)

The station shall have 5-platform and 4-track system to separate alighting and boarding to different platforms. (Fig. III-6-7, Photo.).

The width of central boarding platform shall be 9 m. including the width of stairs of 4.5 m. and the distance from the wall of stairs to the platform edge of 2 m. By preparing 4 stairs,

4.5 m x 3,000 persons/m/hr. x 4 stairs = 54,000 persons/hr.,

can enter the platform.

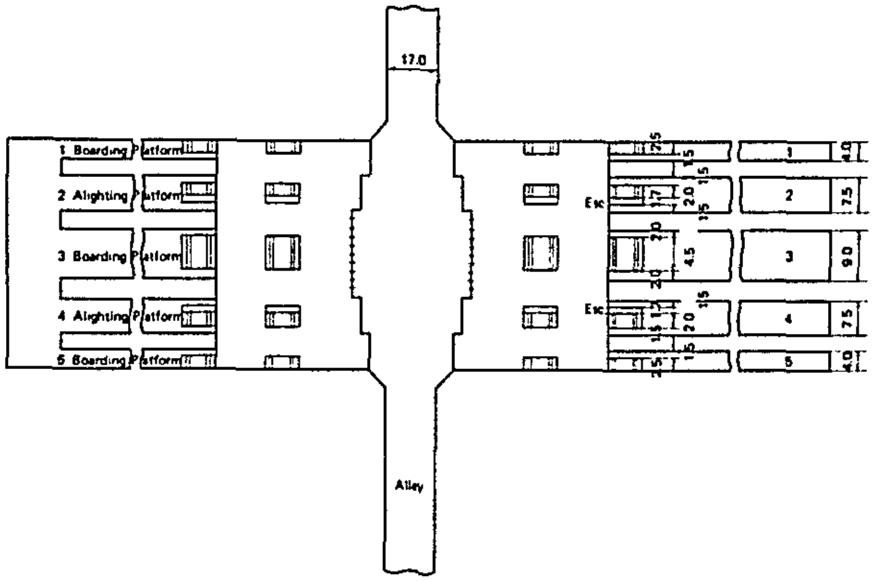


Fig. III-6-7 Terminal Station (Alternative-A)

The boarding platform shall have width of 4 m. including 2.5 m. stairs. By 4 stairs,

2.5 m. x 3,000 persons/m/hr. x 4 stairs x 2 platforms
= 60,000 persons/hr.,

can enter the platform. Consequently the total boarding capacity will be;

54,000 persons/hr. + 60,000 persons/hr. = 114,000 persons/hr.,

This is sufficient for the estimated passengers of about 540,000 persons/day.

The second and fourth alighting platforms shall be equipped with escalators and stairs of 2 m. wide in preparation for failure or maintenance work of the escalators. Assuming the distance from stair-wall to platform-edge to be 1.5 m., the width of the platform becomes 7.5 m.

Equipping 4 escalators to a platform, the capacity to handle passengers will be;

(2 m x 3,000 persons/m/hr. + 9,000 persons/escalator x 0.75 efficiency) x 4 sets x 2 platforms = 102,000 persons/hr.,

which is sufficient for the alighting passengers of about 480,000 persons/day.

A 17 m. wide passage crossing the central part of the platforms shall be prepared for free passing. Assuming 15 m. of the above passage is used for the direction of main flow of rush hours;

15 m x 3,600 persons/m/hr. x 2 sides = 108,000 persons/hr.,
can pass in the direction of rush-hour flow, and this figure balances with the boarding and alighting capacity of the platforms.

The counter-direction capacity in rush hours is,

2 m x 3,600 persons/hr. x 2 sides = 14,400 persons/hr.

If the number of passengers to the counter direction in rush hours is more than the above, the width of the passage should be increased.

The length of the platform shall be 310 m. to accommodate 12-car train and 300 m. of it shall be covered with roof, except for margins at the both ends.

(2) Alternative-B (3-platform and 4-track system)

The second, third and fourth platforms of the Fig. III-6-7 will be constructed at the beginning with the consideration of further extension as shown in the Fig. III-6-7 for future. (Fig. III-6-8 and Photo).

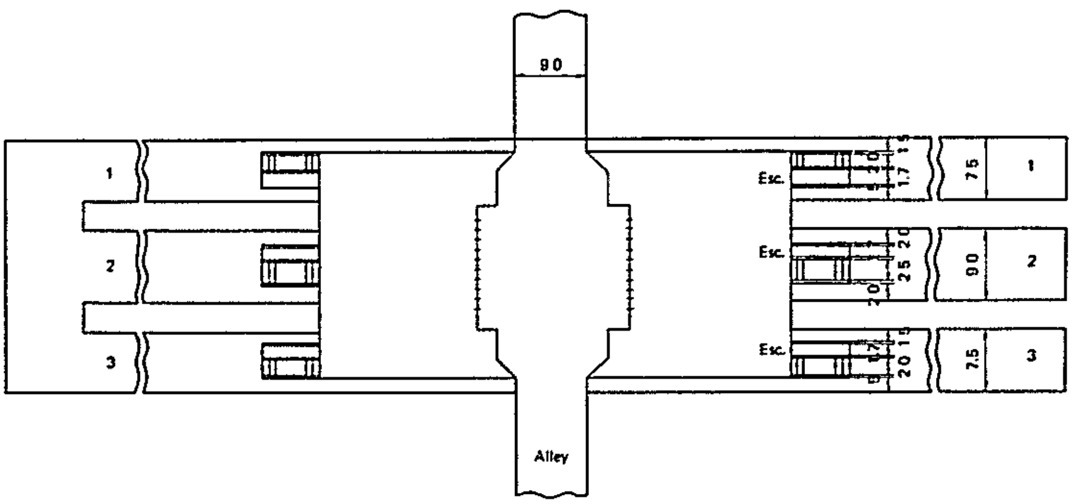


Fig. III-6-8 Terminal Station (Alternative-B)

Central platform will be used most frequency, because of the layout, therefore, the platform shall also be used jointly for boarding and alighting, with escalators installed.

Assuming the stairs to be both-side type, each two sets of 2.5 m. stairs and escalator for the central platform, and 2 m. stairs and escalator to the both outer side platforms, the capacity will be;

(2.5 m. + 2 m. + 2 m.) x 3,000 persons/m/hr. x 2 sides

+ 9,000 persons x 0.75 efficiency x 3 platforms x 2 sides

$\fallingdotseq$ 80,000 persons/hr.

The length of platform for No. 1 Line shall be 235 m. to accommodate 9-car train and for the other lines shall be 160 m. to accommodate 6-car train. The platforms shall be covered with roofs except for 5 m. length at each end for the convenience of future additional construction and reducing the time of turning back of trains.

6-2-2 Intermediate Station

(1) Alternative-A (3-platform and 2-track system)

Stations shall have 3-platform and 2-track system consisting of boarding and alighting platforms. (Fig. III-6-9 and Photo.

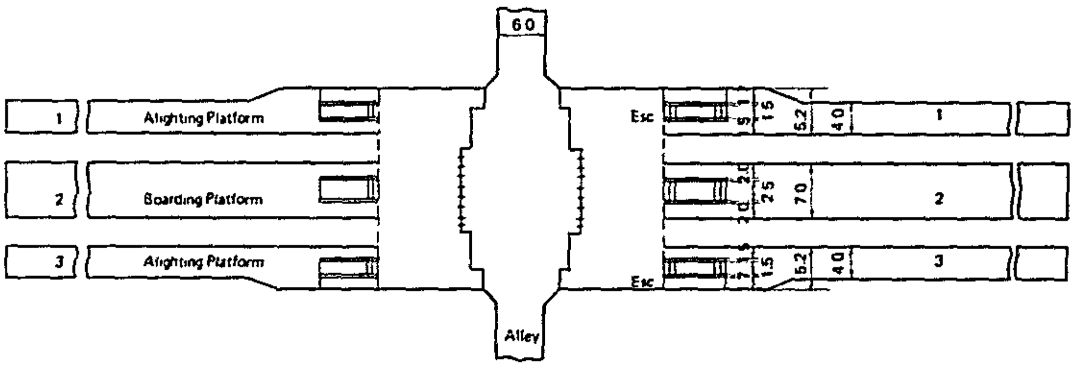


Fig. III-6-9 Intermediate Station (Alternative-A)

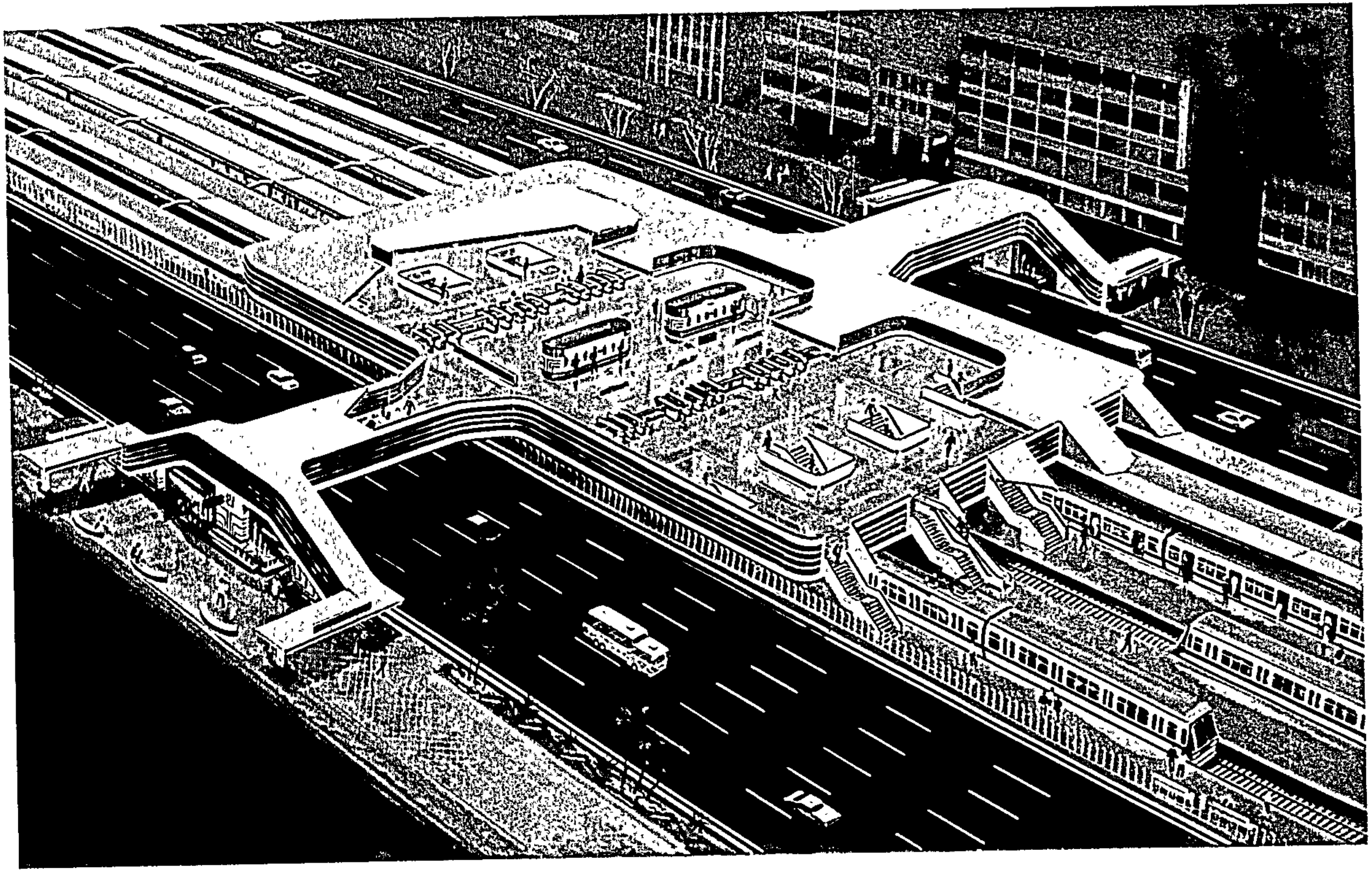
The central platform shall be only for boarding, arranging alighting platforms to both outer sides.

The standard width of the central platform shall be 7 m. with 2.5 m. wide stairs and distance of 2 m. from the wall of stairs to the platform edge.

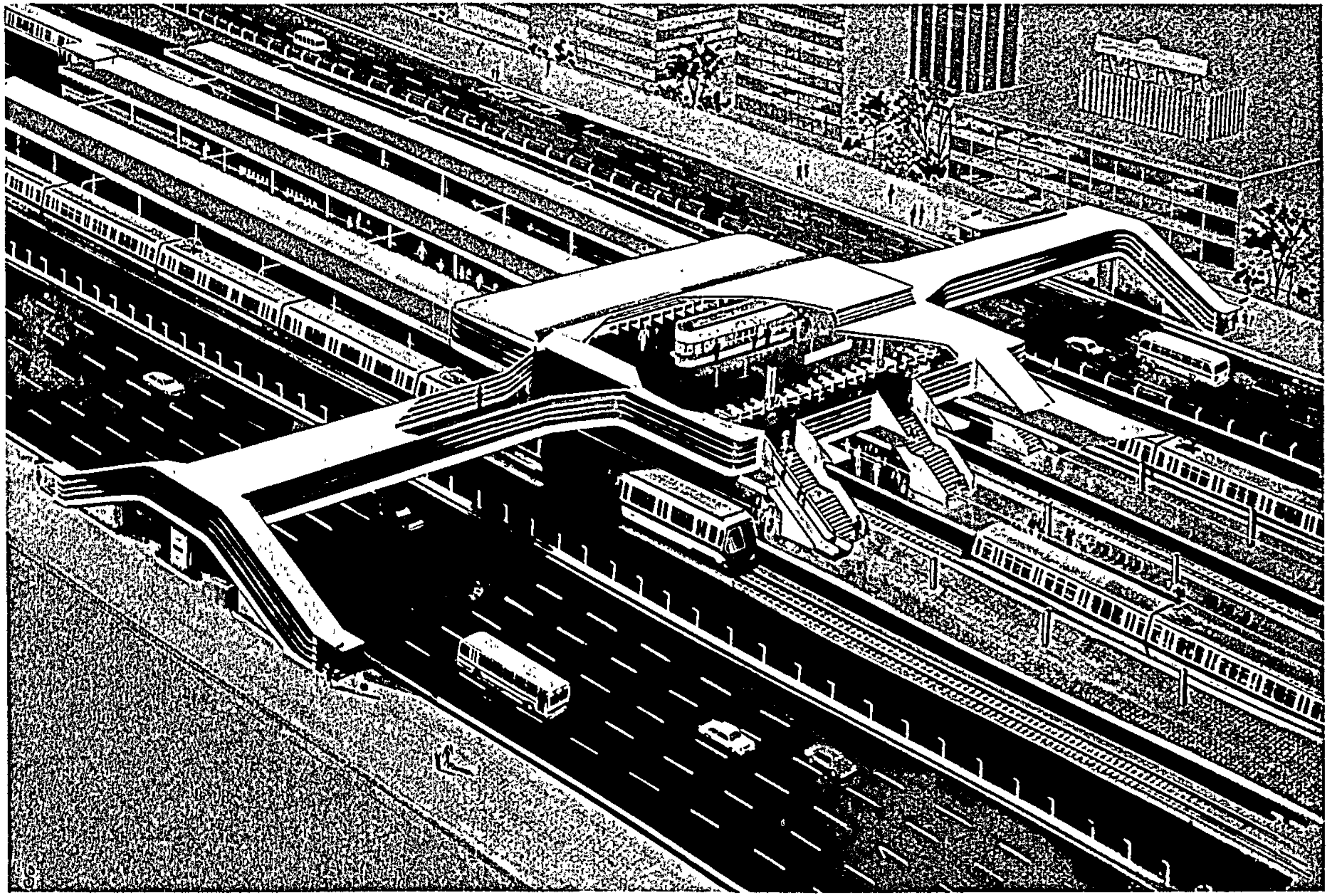
In this case, the capacity of both-side type stairs will be,

2.5 m. x 3,000 persons/m/hr. x 2 stairs = 15,000 persons/hr., which is sufficient for the passengers of about 70,000 persons/day.

As alighting platforms are used only by ascending passengers, escalators will be equipped besides stairs. Assuming the width of the escalator to be 1.7 m. and the stairs, 1.5 m. and the distance from the stair-wall to the edge of the platform edge to be 1.5 m., the width of the platform shall be 5.2 m. at the foot of stairs and 4 m. at other places. (Stairs are necessary in preparation for failure of escalator



Terminal Station (Alternative-A)



Terminal Station (Alternative-B)

and its maintenance.)

The capacity of both-side stairs will be;

9,000 persons/hr x 0.75 efficiency x 2 sides

+ 1.5 m. x 3,000 persons/m/hr. x 2 sides

= 22,500 persons/hr.

Total capacity of the both-side platforms will be;

22,500 x 2 = 45,000 persons/hr.,

which is sufficient for the passenger of about 210,000 persons/day.

Above capacity of stairs for the boarding passengers at central platform is rather small. However, countermeasures can be taken by enlarging the width of stairs or enlarging the concourse and installing 4 stairs.

For the stations handling a great number of passengers, increase of stairs is recommended to empty the passenger quickly from the platform. In the case of four stairs, the capacity of handling passengers will be doubled.

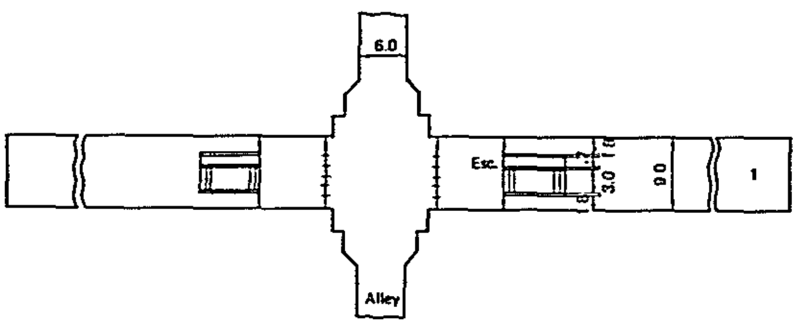
The passage shall be of 6 m. wide and to cross the central part of the platform with the capacity of;

6 m. x 3,600 person/m/hr. x 2 sides = 43,000 persons/hr.

The length of the platform shall be 310 m. to accommodate a 12-car train and covered with a roof of the train length of 300 m.

(2) Alternative-B (1-platform and 2-track system)

An island-type platform and two tracks will be prepared. (Fig. III-6-10 and Photo).



A Fig. III-6-10 Intermediate Station (Alternative-B)

Both escalators and stairs shall be installed for joint use of boarding and lighting.

The width of the platform shall be 9 m., equipped with 1.7 m. wide escalators and 3 m. wide stairs.

The capacity of both-side stairs will be;

$$(3 \text{ m.} \times 3,000 \text{ persons/m/hr.} + 9,000 \text{ persons} \times 0.75 \text{ efficiency}) \times 2 \text{ sides} \div 32,000 \text{ persons/hr.},$$

which is sufficient for about 150,000 boarding and alighting passengers per day.

To counter the future increase of boarding and alighting passengers, two methods are considered; one is to install wider platform at the beginning and the other is to expand concourse and add stairs and escalators in accordance with necessity.

However, the latter is recommendable.

The passage shall be prepared to the central as shown in the final layout, with the width of 6 m. The capacity will be;

$$6 \text{ m.} \times 3,600 \text{ persons/m/hr.} \times 2 \text{ sides} = 43,000 \text{ persons/hr.}$$

The length of the platform of No. 1 Line shall be 235 m. for 9-car train, and for the other lines, 160 m. to accommodate 6-car train each covered with roof of 225 m. and 150 m. long, respectively.

6-2-3 Extension of Platform

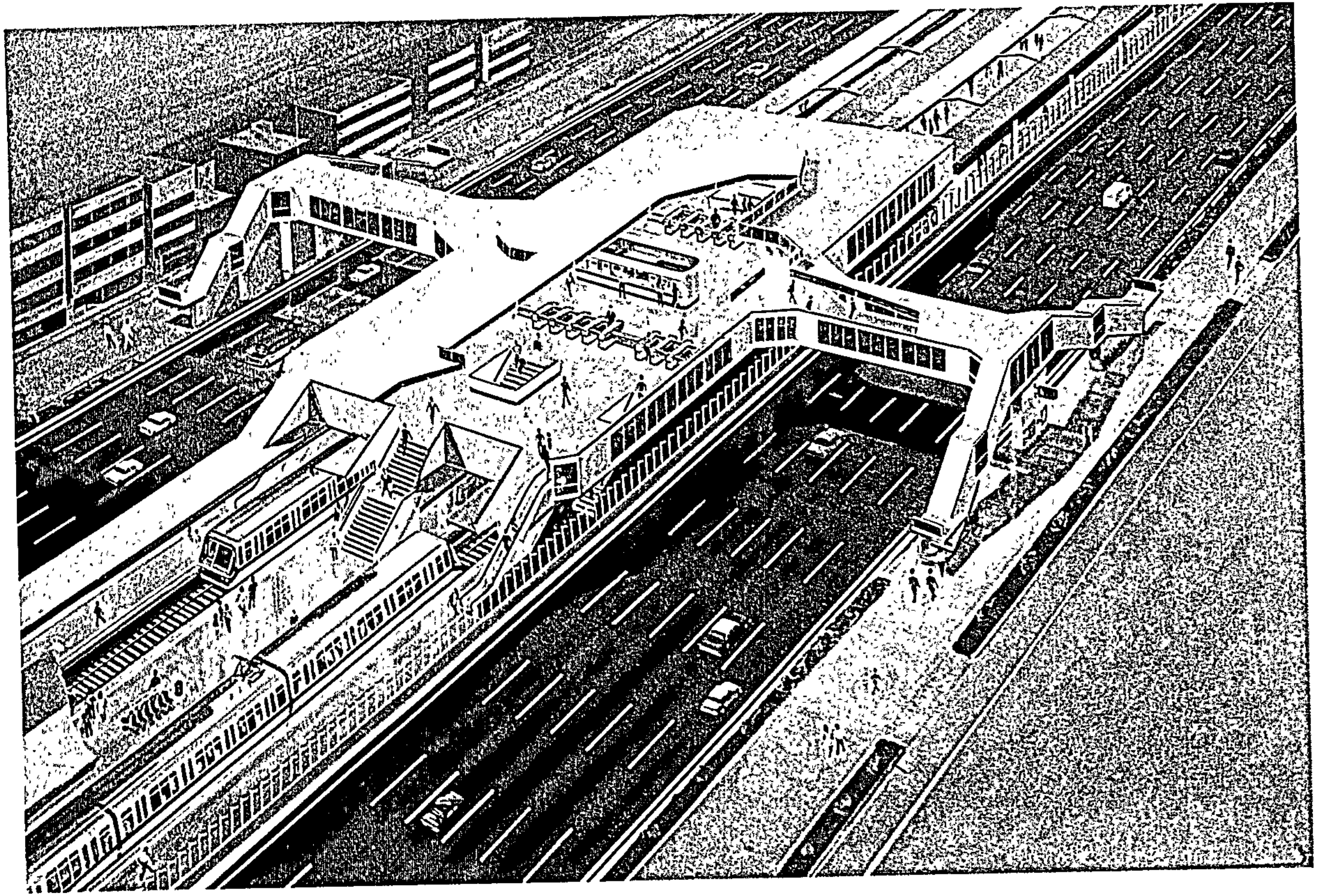
The No. 1 Line will operate 9-car train, No. 2, 3, 4 and 5 Line, 6-car train in the initial stage. However, the train length will be increased step by step beginning with 6-car and then to 9-car, and then to 12-car.

The idea is to operate 12-car train on all lines in future.

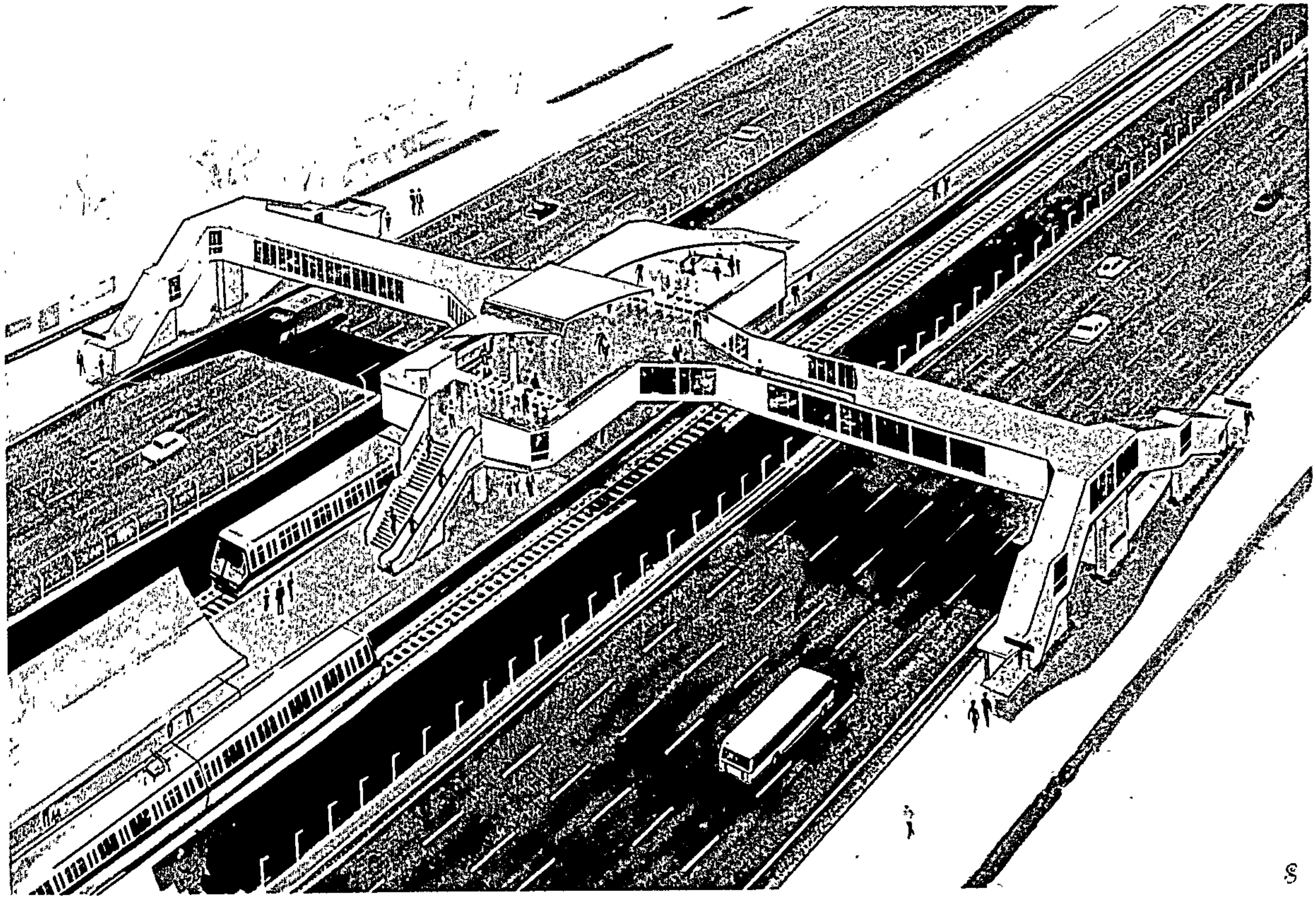
In the case of Alternative-B, platforms are prepared in train length and this entails their extension later.

In case of the terminal station, installing platforms with needed area at their rear for future expansion is preferable from the view point of reducing the time for trains to turn back and of the convenience for the extension works.

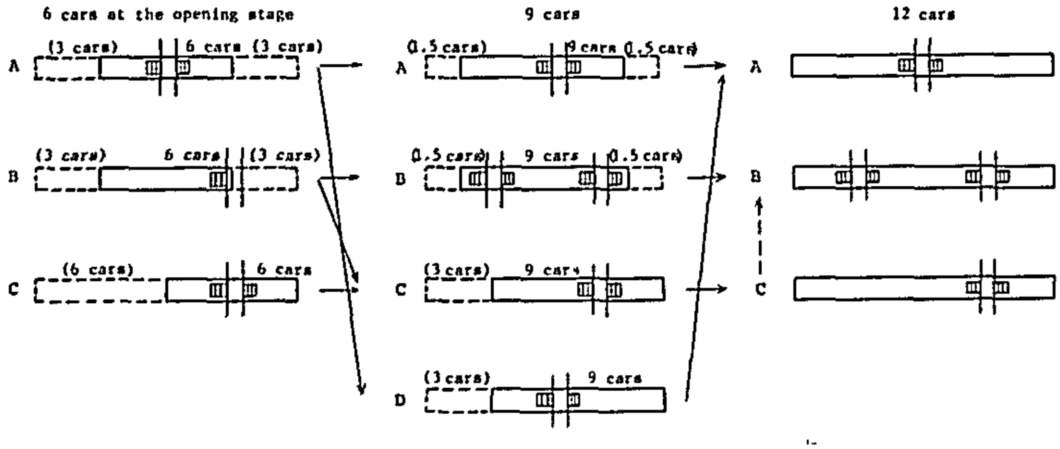
At the intermediate stations, the above two conditions are the same, and in this case several expansion plans can be considered depending on the location of passage. (Fig. III-6-11).



Intermediate Station (Alternative-A)



Intermediate Station (Alternative-B)



Stairs and Escalators

By means of 3m-wide stairs and a two-person-on-a-step escalator, with its running direction set to larger traffic flow, about 13,000 passengers can be transported in one hour.

2m x 3,000 pass/h + 6,750 pass/h = 13,000 pass/h

Therefore, some stations can do without two-side stairs. It depends on the number of passengers. The more stairs being installed, the faster the passengers can move. But, two stairs necessitate two overbridges which may impair the beauty of the city.

Items to be studied

Number of passenger - boarding and alighting
Cost for transferring A.T.O.
Levelling of passengers' ride

Fig. III-6-11 Idea of Platform Extention

What should be considered in selecting adequate alternative are number of passengers, cost for transfering ground equipments such as ATC, and boarding of passengers to be even on all cars throughout the line.

6-3 Passenger Service Facilities

6-3-1 Automatic Fare Collection System (A. F. C.)

(1) Considerations on the A. F. C. system

Amont the jobs related to a station business, this system aims at labor-saving and rationalizing the job related to booking and wicketting and the supporting jobs related to them.

To automate the fare collection system, the system depends entirely on the tariff, tariff on a uniform basis or on a mileage basis, and tickets to be used, single ticket only or book of tickets (stored ride type) also. The system in this project is established standing on the tariff on a uniform basis, considering that the investments for the tariff on a mileage basis becomes larger, total route length is only 77 Km for the time being, and the idea of Mexican commission is also in this direction. The introduction of book of tickets, however, have also many advantages, and this idea is also presented as a alternative.

(2) Automatic fare collection system

The system consists of the following 3-systems:

1) Automatic booking system

a) Automatic vending system

The system is to sell tickets automatically, and the disposition of cash and totalization of selling data are performed without using manpowers.

b) Book of tickets vending system

The system is to sell a book of tickets automatically, for example a book is effective 50 times, and a number of rides encoded on the ticket is discounted by each passing of entry gate.

2) Automatic ticket checking/collecting system

The automatic ticket checking/collecting system checks the passing passengers to and from the station precincts automatically, and consists of automatic gates (wicket) which controls the passengers comming-in or out-from the station premises at the wicket and a gate controller which integrately controls these automatic gate.

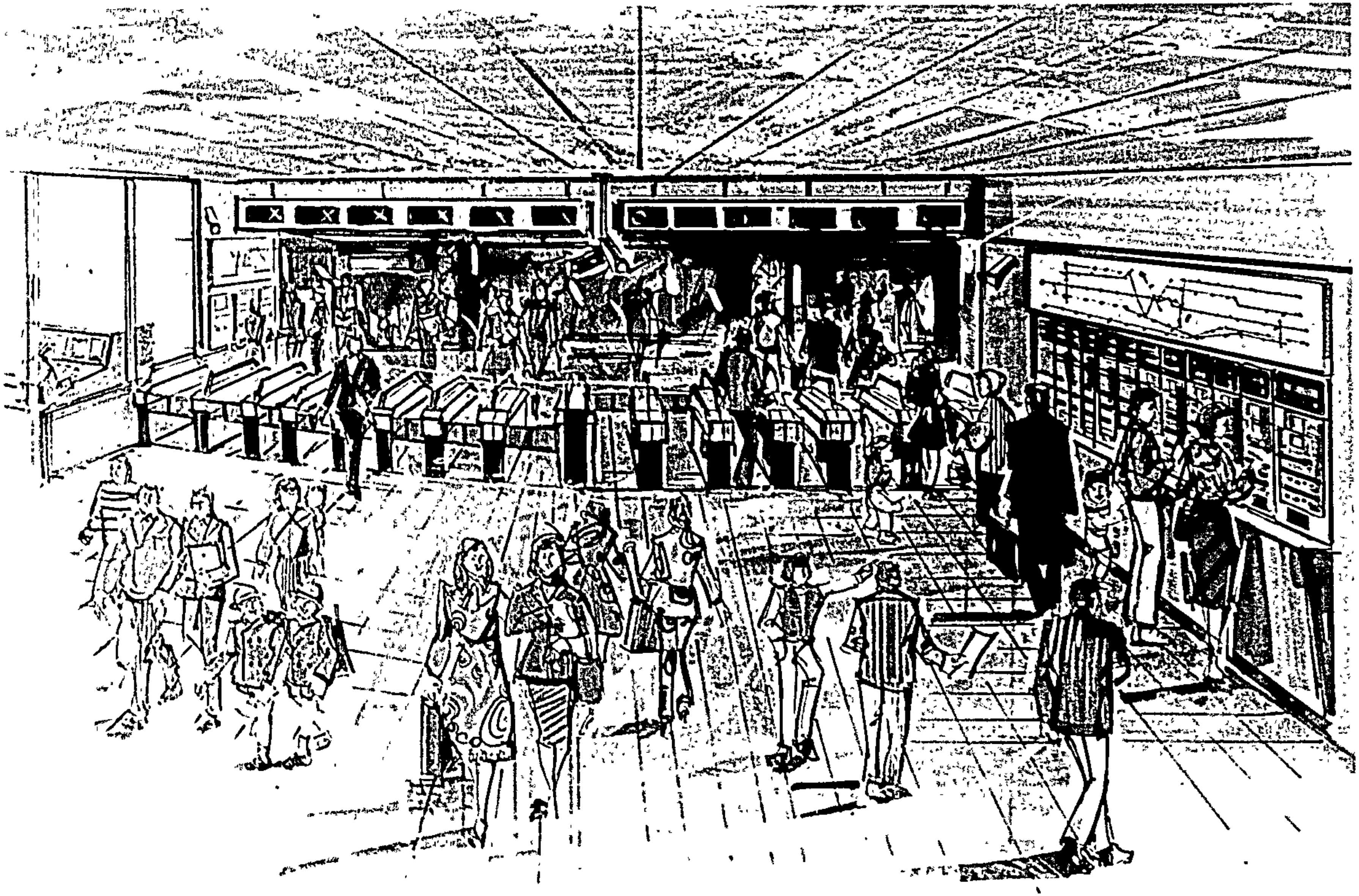
3) Automatic back up system

a) Monitoring system

The system has functions to monitor the operating condition of each A. F. C. equipment as well as functions to watch over passengers and guides and conducts them from the control room at the station.

b) Data concentrating system

The system has functions to collect and totallize data of selling or examining tickets and data necessary for the maintenance of each A. F. C. equipment as well as to transfer those data to the central processing system.

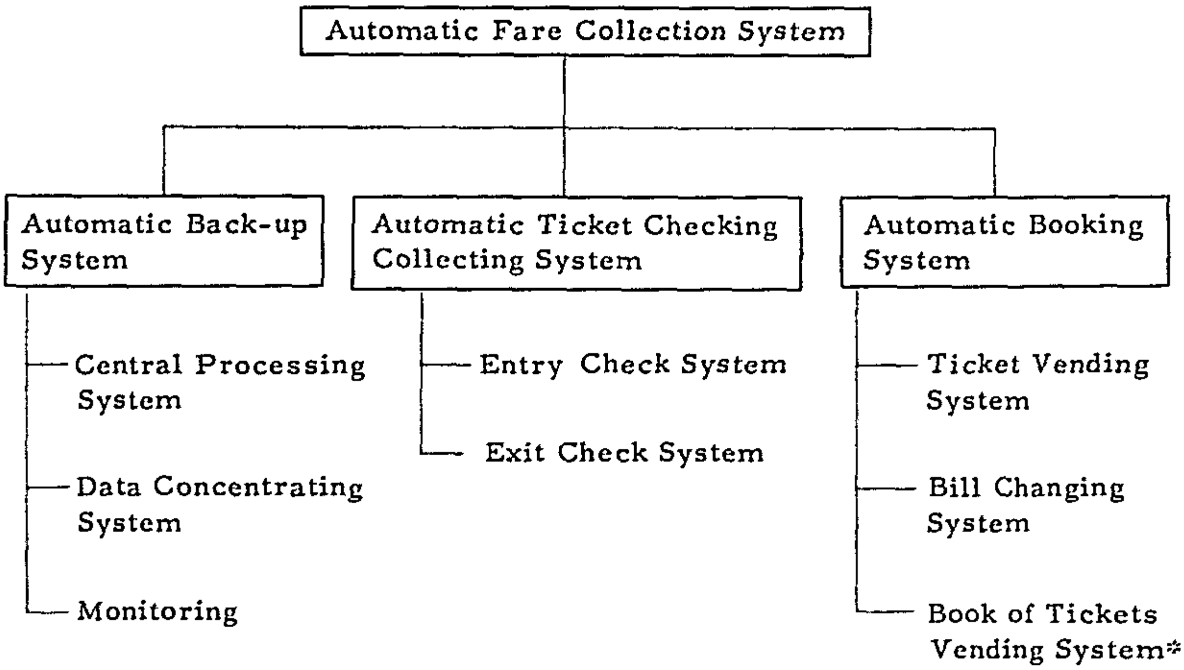


Automatic Fare Collection Equipments in a Station

c) Central processing system

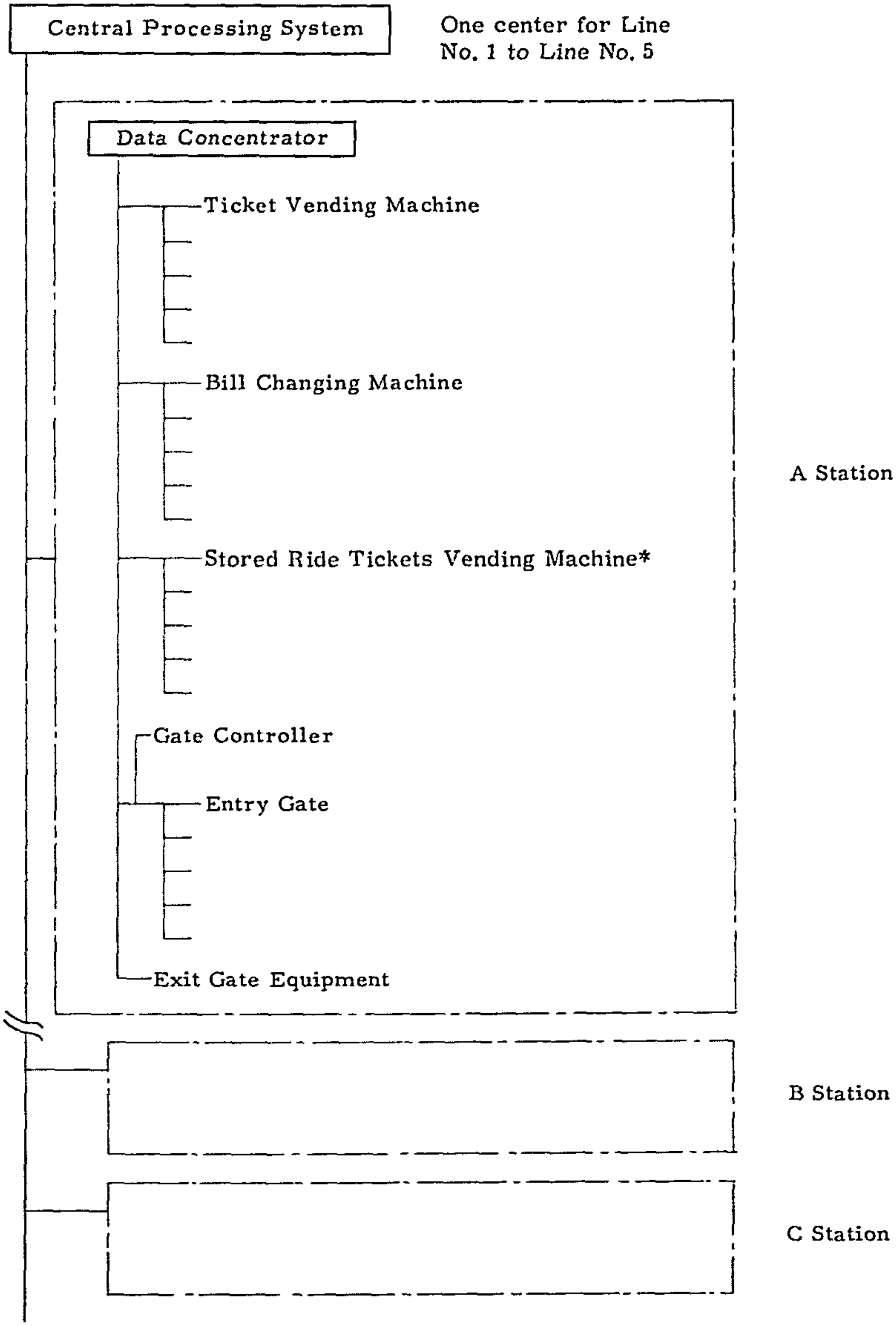
The system is on-line connected with data concentrating systems of the stations, centralize the collection of various data and processes them as required for the statistical inspection or maintenance.

Fig. III-6-12 is the functional diagram of the system necessary for the A.F.C. system as described. System of complete equipment is shown in the Fig. III-6-13.



* Required only in the case of introducing book of tickets system.

Fig. III-6-12 Function Diagram of Automatic Fare Collection



Note) * Required only in the case of introducing stored ride ticket system

Fig. III-6-13 System of Complete Equipment

(3) Equipment required

Major equipment required for the automatic fare collection system are as follows:

Alternative-A is the case handling only single ticket, and alternative-B is handling book of tickets also.

	Alter-native-A	Alter native-B
1) Ticket vending machine with change counting equipment and encording function.	*	*
2) Entry gate for magnetic encorded tickets with 4 flapper type barriers.	*	*
3) Exit gate to make free exit without ticket-collecting function, but functions to prevent reverse entrance is equipped.	*	*
4) Gate controller controls automatic gates.	*	*
5) Bill changing machine automatically exchanges bill into coins.	*	*
6) Data concentrator collects sales data for each station and each vending machine and transfer them to the central processing system.	*	*
7) Central processing system compiles, analyzes, inspects, displays and outputs data collected from stations.	*	*
8) Book of tickets vending machine sells several kinds of book of tickets, equipped with change issuing equipment and encode function.	-	*

Although the Alternative-B requires book of tickets vending machines other than the equipments for the Alternative-A, total investment of A.F.C. equipment for the Alternative-B will be reduced to about 65% of the Alternative-A, because the required number of ticket vending machines can be reduced. This system will be welcomed by the passengers who are exempted from the trouble of buying ticket each time, and may further be welcomed by introducing the fare reduction system.

6-3-2 Escalator

For the convenience of passengers, escalators are equipped to the ascending direction of the platforms of the each station.

Installations of escalators was described in the paragraph 6-2, and the outline of the equipment is described hereunder :

(1) Speed

Speed of 40 to 45 m/min. is desirable in the view of increasing carrying passengers, however, a speed of about 30 to 36 m/min. may be recommendable for the safety of children and aged passengers.

(2) Width

In a station with few expectation of future increase of passenger the width of 800 mm may be economical, however, 1200 mm is recommended for high demand estimation.

(3) Angle (Slope)

Angle of 35° is sometimes employed, however, 30° angle is selected as the value is the standard for many and unspecified passengers.

(4) Horizontal length of platform step

In consideration of the safety of boarding and alighting, horizontal running distance of the step of platforms shall be made to be equal or more than 1220 mm. The value is also required for using wheeled chair for handicaped passengers.

The carrying capacity of an escalator is 9000 person/hr.

7. Electric Power Facilities

7-1 Fundamental Policy for Equipment and Facility Planning

In planning the electric power equipment and facilities, the following points were taken into consideration:

(1) The facilities should be such that is suited to the electric characteristics of electric cars.

(2) The facilities should not constitute an obstacle to the train operation.

(3) Transmission lines, transformers and other important facilities should be a duplex system, and the train operation shall not be influenced even if one of them has gone out of order.

(4) The facilities can easily cope with a possible future increase in transport capacity.

(5) The facilities should be such that may decrease as much as possible the unbalance given to the power source, the inductive disturbance to telecommunication circuits, and others.

(6) In case of trouble in the facilities, the damage should be minimized, and the affected areas should be limited.

(7) Preventive measures should be taken against any accident which may cause injury to human body.

(8) The initial investment for equipment and facilities should be restricted within the required limits, and an additional future investment plan should be taken into due consideration.

(9) There should be chosen the equipment, materials etc., use-proven with high reliability in such a manner as to thus enhance the reliability of the system as a whole.

(10) The facilities should be of easy for maintenance and operation.

7-2 Electrical Operation Plan

7-2-1 Planned Track Routes and Operation Plan

The lines of this suburban railways are as shown in Figure III-1-3, and the operation plan is described in Section 4, and the performance characteristics of vehicles in Section 9. The electric power facilities are to be planned to conform to these plans, and at the same time to cope with the possible future traffic increase easily.

Electric power facilities have been worked out for electric power facilities: Alternative-A and Alternative-B. These correspond to the civil engineering and operation plans: Alternative-A and Alternative-B, respectively.

As the peculiar problems of electric power facilities, the difference in power receiving systems from 230 kV power network produces a great difference in transmission line installation cost. As described later, the Alternative-A is for the new installation of exclusive 2-circuit transmission lines from substations of an electric power company, and the Alternative-B for the power receiving through intermediate branching from the existing transmission lines of the electric power company.

7-2-2 Electric Power Consumption

It is necessary to calculate in advance the electric power consumption required for the running of trains in order to decide substation capacities, and estimate electric power cost for operation, etc.

The following elements are needed for the calculation of electric power consumption:

(1) Electric performance characteristics of electric cars
(2) Train composition of motor cars and trailers
(3) Time of powering, time of coasting, braking time, and stoppage time
(4) Train operational restrictions such as speed limits
(5) Gross weight of train
(6) Station-to-station distance
(7) Gradients and radius of curvature, of tracks, and their lengths
(8) Acceleration and running speed
(9) Running resistance

For more accurate calculation of the electric power consumption, more dètailed data will be required.

7-2-3 Electrical Operation System

In determining the electrical operation system for this suburban railway, the following points must be taken into consideration:

(1) Electric power consumption needed for train operation
(2) The most suitable place to receive the electric power, considering of the electric power network.

(3) The permissible umbalance and voltage fluctuation etc., given to the electric power network by the electric loads.

(4) The power feeding system shall be such that can compete the prescribed train operation plan, its slight change, and ordinary disorder of train operating schedule, etc.

(5) Bad influences are not given to telecommunication circuits etc., laid near the feeder circuits.

(6) It should be an electrical operation system suited also to the inter-urban transportation by future extension of the track route.

When taking these points into consideration for the planning of the electrical operation system of this suburban railway, the adoption of single-phase AC 25 kV 60 Hz system can be considered as a proper choice.

The AC power system operation within urban area, however, has the possibility of giving inductive disturbance to telecommunication circuits installed near the tracks. Therefore, in the communication circuits it is needed to take counter measures against inductive disturbance such as the use of cables, but also as the feeding system, there must be adopted a system which will reduce inductive disturbance, such as AT feeding system. Further with respect to the vehicles, such measures should be taken as the adoption of control method of reducing inductive disturbance in the speed control system, the use of filters, etc., leading to the comprehensive measures to be taken both in ground facilities and vehicles.

7-3 Electric Power Receiving Plan

7-3-1 Electric Power Network

The electric power networks in the Metropolitan area of Mexico are composed of 400 kV and 230 kV systems, as shown in Appendix Figure III-7-1.

The 230 kV system substations are installed at various points as required within the area and are connected together by loop transmission lines. The 3-phase short-circuit capacity of these 230 kV system substations is now more than 5,000 MVA and is said to exceed 10,000 MVA in the future. To such powerful source as this, the electric railway single-phase loads will give only small unbalance in voltage and will not cause any trouble. This suburban railway, if it adopts AT feeding system, will be able to decrease the inductive disturbance to telecommunication circuits and moreover enlarge the intervals of traction substations, and thus save the construction cost through the planning of appropriate power receiving locations.

7-3-2 Locations of Substations

To determine the locations of substations suitable to an electrical operation which will receive the electric power from a 3-phase electric power network, the following items need to be reviewed:

(1) Selection of sites suitable for receiving electric power when considered from the side of electric power network

(2) The sites to be located near the load centers of the railway

(3) Capable of receiving and feeding the power required for the electrical operation

(4) Capable of securing the required catenary voltage under the worst conditions at the ends of feeding circuits

(5) Good conditions for constructing the substation

There are only little elements of restriction in the selection of sites capable of receiving power from the side of electric power network, since the network has been fully developed in the Metropolitan area of Mexico as mentioned above.

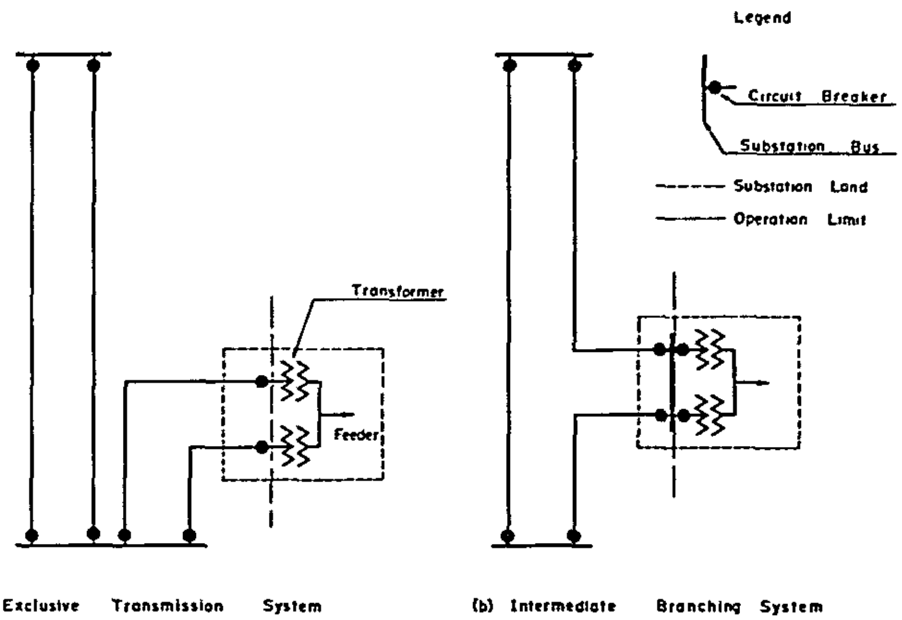
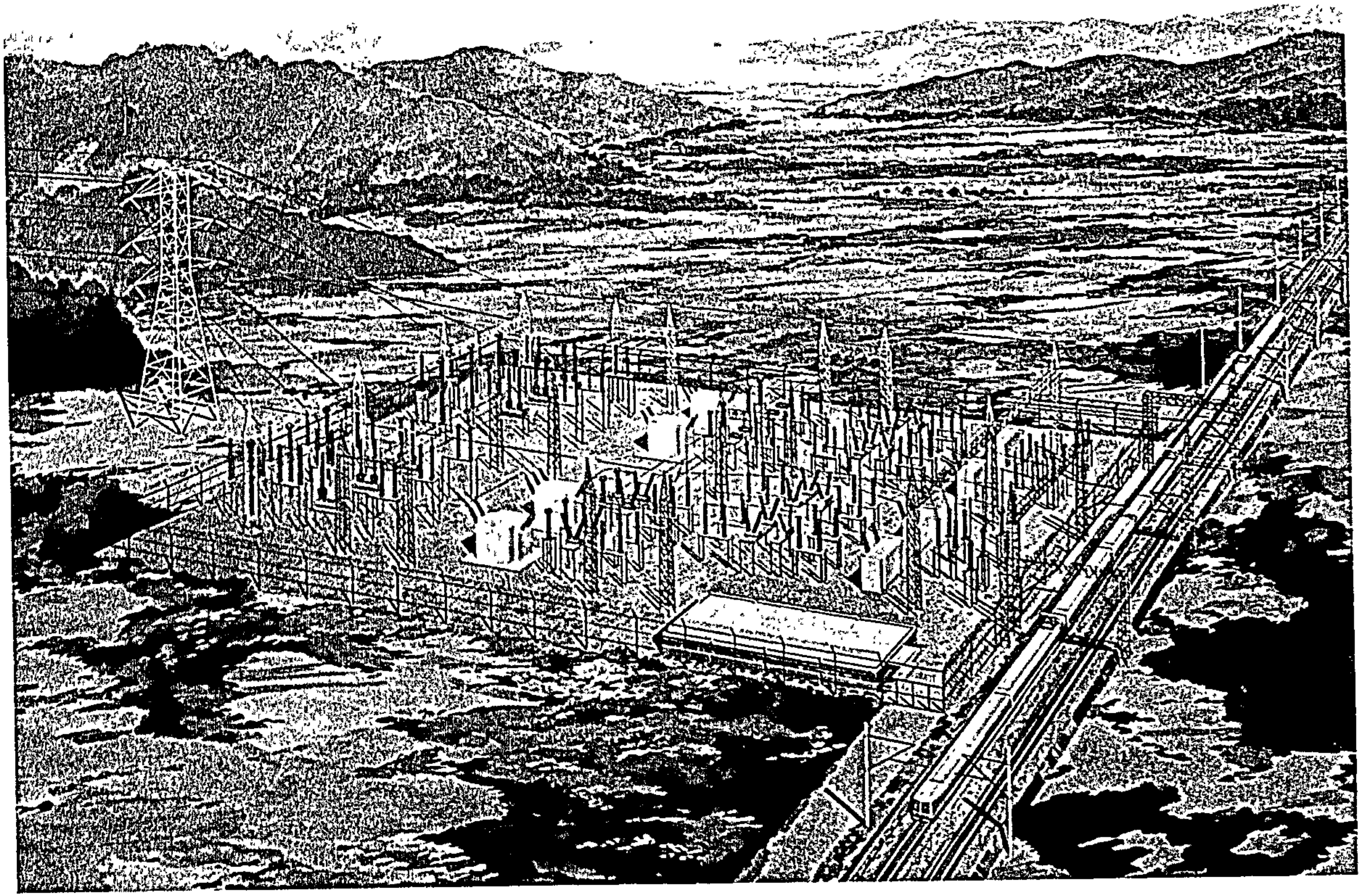


Fig. III-7-1 Power Receiving System



Electric Power Substation

The construction cost of transmission lines and the equipment layout of substation, however, will be greatly influenced by whether or not the branching is possible from 230 kV transmission line as shown in Figure III-7-1 (b), for securing the power for electrical operation. In case where the branching from the transmission line is permitted, the construction cost of the power receiving system can be reduced, because the substation is constructed near the crossing of transmission line and railway track.

The location of substation as considered on the basis of load center will be near Xalostoc as a first suitable choice. Fortunately, there is a 230 kV transmission line across the railway track near Xalostoc, and the installation of this traction substation will also be convenient to the feeding of the railway lines No. 3 and No. 4 and be able to feed the whole lines of the railway at the time of its inauguration.

Yet the installation of one more substation is desirable in order to avoid voltage drop at the farthest catenary of the Line No. 1 and the inability of train operation over the whole line in case of power failure at Xalostoc Substation.

The suitable location of the second substation is somewhere along the Line No. 1 which has a large traffic volume. The load center of the Line No. 1 is near Periferico, such method can be considered as will have a substation constructed near there and install a transmission line from Sta. Cruz Substation or Magdalena Substation of the electric power company to receive power. To save the construction cost, however, there can be considered another method of receiving power through intermediate branching from a transmission line near Las Torres where the Line No. 1 and 230 kV transmission line come across with each other.

In the latter case, the location will deviate a little from the load center of the Line No. 1, but the substation can be installed at Las Torres, considering that: (1) the unbalance is negligibly small against the electric power network with a large short-circuit capacity and (2) when the railway line is extended to the east beyond Los Reyes in the future, the location of the substation will come rather nearer to the load center.

7-3-3 Substation Capacity

The substation capacity depends on the electric power consumption determined by traffic volume at rush-hour zone. As a result of estimation the loads of substations, are given in Table III-7-1.

Table III-7-1

Approximated Estimated Values of Maximum Loads of Substations

(in MVA)

Name of Substation		Xalostoc	Las Torres or periferico	Total
Alter-native-A	Initial	70	25	95
	Future	100	35	135
Alter-native-B	Initial	60	20	80
	Future	85	30	115

The capacity of feeding transformers will be decided on the basis of this estimated loads and in consideration of operations at abnormal time and future change in transportation etc. As an outline, it is planned at first to install two transformers (50 or 75 MVA per phase) at Xalostoc and one transformer at Las Torres. In the future when the traffic has been increased, this capacity of those transformers shall be doubled.

It can be considered that in further future when the load is increased, another substation is installed near Tlalnepantla, which will support the loads of Lines Nos. 2, 4 and 5, and thus decrease the load on the Xalostoc Substation.

7-3-4 Transmission Line Branching

A simple example is already given in Figure III-7-1 on the method how to connect to the electric power network in order to receive the electric power for electrical operation.

The Figure III-7-1 (a) shows the method of receiving power by installing an exclusive transmission line through the 230 kV bus bar at substation of the electric power company. In this case the system can do without the 230 kV bus bar which would otherwise be installed in the traction substation.

The Figure III-7-1 (b) shows the method of π-type branching of one circuit on the midway of 230 kV transmission line. In this case, there is no need of constructing exclusive transmission line, but it is needed to incorporate the area up to 230 kV bus bar of the traction substation into the operation dispatching system of the electric power company, in consideration of the overall operation of the electric power system as a whole.

7-4 Substation Facilities

7-4-1 Voltage Unbalance and its Reducing Measures

In the electrical operation by single-phase AC system, voltage unbalance is generated in the power source network. This influences the 3-phase induction motors or generators. The negative phase-sequence current generated by unbalance will produce adversely revolving magnetic field, causing the torque reduction in induction motors, increasing the copper loss of rotor and heating stator windings. To the AC generators, it induces the second harmonic current to the rotor, worsening the wave forms of generated voltage and heating stator coils. To the rectifiers, it promotes the generation of higher harmonics in the rectification and increases the deformation of voltage wave forms. In the practical use, however, if the voltage unbalance is limited within 5%, the extent of influence will be kept within the design and manufacturing tolerances, thus raising no problem at all.

In this suburban railway, if can be considered that the large short-circuit capacity of the power source will result in small unbalance factor not exceeding 1 %.

7-4-2 Types of Connection of Feeding Transformers

To reduce the unbalance given to 3-phase power source network, there is a method of using as the feeding transformer a special transformer, that is, 3-2 phase converter. This special transformer gets 2-phase electric power from balanced 3-phase electric power, and also has the function of reverse conversion. The Figure III-7-2 shows some typical types of connection of 3-2 phase conversion transformer, that is, Scott connection, Woodbridge connection, Modified Woodbridge connection and Leblanc connection.

Particularly the Scott connection is composed of two single-phase transformers of simple structure, which have a practical advantage that they can share a part of iron cores in common if held in one tank. Scott-connection is applicable to both the AT feeding system and the BT feeding system. Graded insulation cannot be given to the primary winding of the transformer of Scott connection.

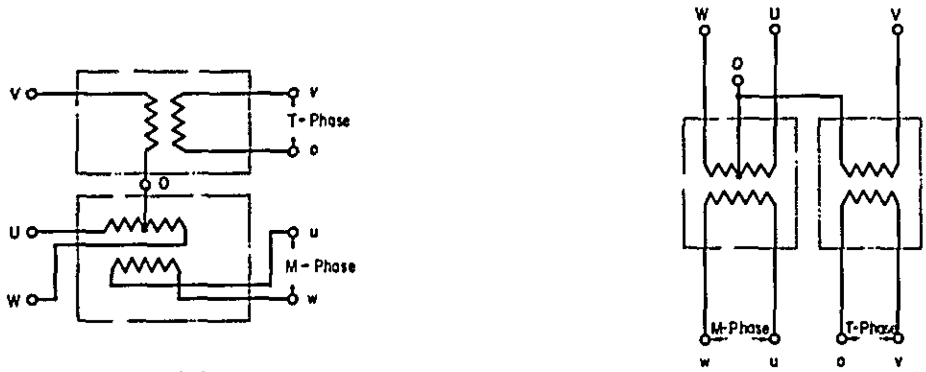
In case of need for direct grounding of the neutral point of the primary winding, such connection as will have start-type winding on the primary side, for example the modified Woodbridge connection, is used. The characteristic features are:

(1) The primary winding is of star connection

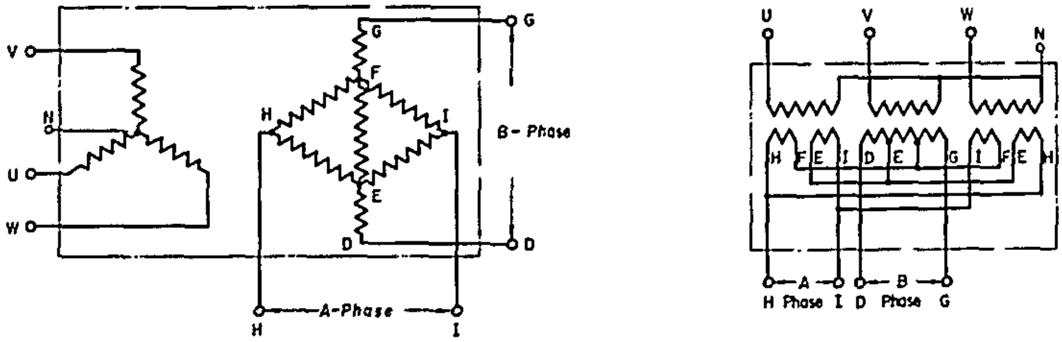
(2) Each winding of the secondary side is symmetric, easy to manufacture, and easy to coordinate electric characteristics

(3) The secondary side is of delta connection, having effect of decreasing the 3rd and 3n-th higher harmonics

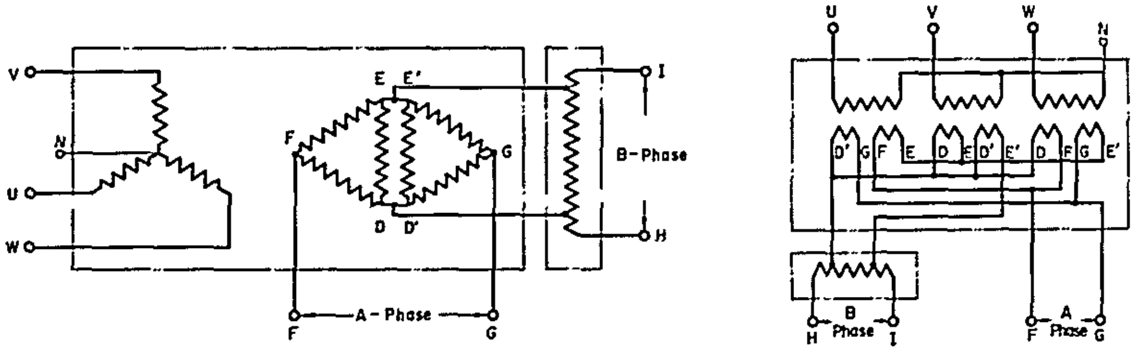
(4) If the neutral point on the primary side is grounded, the graded insulation is practicable, and so on



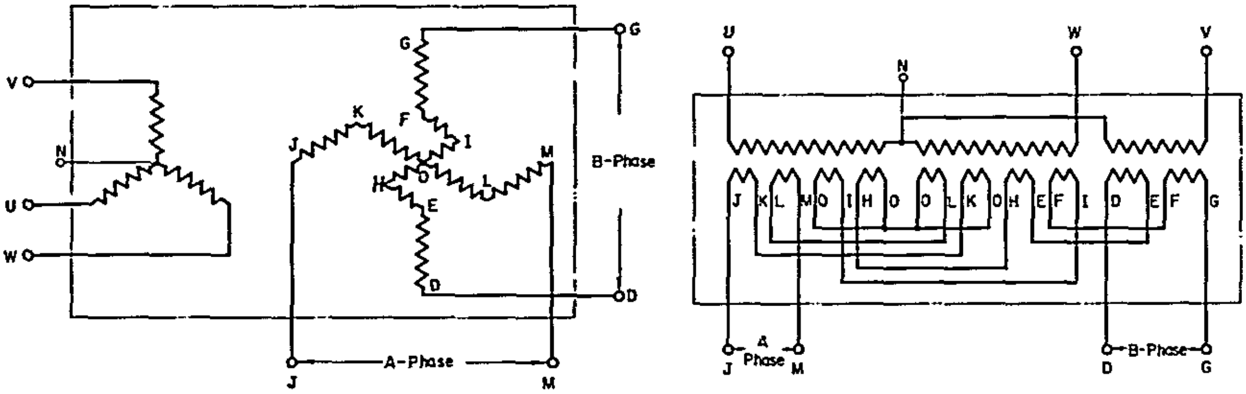
(a) Scott Connection



(b) Woodbridge Connection



(c) *Modified Woodbridge* Connection



(d) Leblanc Connection

Fig. III-7-2 Connection of 3-2 Phase Converter Transformer

It is recommendable to adopt Scott connection system in this suburban railway, for the reason that this type of connection permits the economical installation and its enlargement suited to the increase in amount of transportation. Practically in the beginning, a M-phase transformer will be installed in Las Torres substation and 2 M-phase transformers on the shape of V-connection in Xalostoc substation, the electric load of the inauguration time is small and will cause no problem. It is possible to complete Scott connection transformer system by adding T-phase transformers to meet traffic increase in future.

The Table III-7-2 shows various connection systems and unbalance factors. As seen from the Table, in Scott connection or Modified Woodbridge connection, the unbalance factor gets zero if the loads by a pair of phases (P_M and P_T, or P_A and P_B) are equal. The V-connection will not reduce the unbalance factor to zero but will be better than single-phase connection.

7-4-3 Insulation Design

Insulation design needs to be performed in a rational manner to achieve safety, throughout the transmission lines, substations, feeder circuits and electric cars. The insulation of each part of high-voltage circuits must resist the impulse-voltage test prescribed for each circuit voltage. Mexico City, situated on the highland, has a low atmospheric pressure which gives low dielectric strength of the air. According to the law of Paschen, the arc generated at a gap in uniform electric field is easier to occur as the atmospheric pressure gets lower. Therefore, the insulation clearance must be taken larger at highlands than lowlands.

In the 25 kV AC feeding circuits, for example, as is the case with the Japanese National Railways, the clearance between line parts and earth is specified 300 mm as standard. For Mexico City, however, where the atmospheric pressure is reported to be around 590 mmHg, the clearance between line parts and earth will be specified 400 mm as standard. The standard height of contact wires and the construction gauge are shown in Fig. III-7-7.

Table III-7-2

Unbalance Factors of Various Types of Connections

	Loads by Phases(kVA)	Unbalance Factor (%)
Single-phase connection	P_L	$ZP_L \times 10^{-4}$
V-connection	P_1, P_2	$Z\sqrt{P_1^2 - P_1P_2 + P_2^2} \times 10^{-4}$
Scott connection	P_M, P_T	$Z\ (P_M - P_T) \times 10^{-4}$
Modified Woodbridge connection	P_A, P_B	$Z\ (P_A - P_B) \times 10^{-4}$

Z : Percentage impedance based on 10,000 kVA of 3-phase power source system, at the receiving point.

7-4-4 Supervisory Remote Control

With the recent progress in supervisory remote control technique and the improvement in performance of protective relays, 230 kV system substations are unmanned, and the remote supervision and control system from distant control center is developed and acceptable.

It is desirable to centralize the control dispatchings at one place with consideration to power feeding from substations, etc., detection of facility abnormalities, smooth exchange of informations on train operation, and communication with maintenance personnel etc. The location considered for the control center is somewhere near San Lazaro, but it is desirable to put it in the proximity to the management and administrative organization.

The supervisory remote control system is provided with the function of collecting the information relative to electric power and dispatching instructions to substation equipment, etc.. Lack of proper arrangement of information and sufficient review of control items at the time of planning may cause confusion in the judgement of the dispatcher and disturb the dispatching of proper instructions.

7-5 Feeding System

7-5-1 AT Feeding System and BT Feeding System

There are many systems considerable as single-phase AC feeding system. Among them, the AT feeding system and BT feeding system have much experience of actual application as the systems which have lower inductive disturbance given to telecommunication circuits.

The Figure III-7-3 gives the general concept of both systems. Either of the systems reduces the current flowing through rails and thus lower the leakage current to the earth in order to reduce the inductive disturbance to telecommunication circuits. For this purpose feeder is needed to replace rails.

The main facilities of both systems are compared in Table III-7-3.

Table III-7-3

Comparison of AT Feeding System and BT Feeding System

	AT Feeding System	BT Feeding System
Catenary voltage	25 kV	25 kV
Substation feeding voltage	50 kV	25 kV
Voltage drop	Small	Large
Feedable distance	Long	Short
Principal facilities	Messenger wire	Messenger wire
	Contact wire	Contact wire
	Feeder	Negative feeder
	Protective wire	—
	Overhead ground wire	Overhead ground wire
	Autotransformer	Booster transformer
BT sections	None	Exist

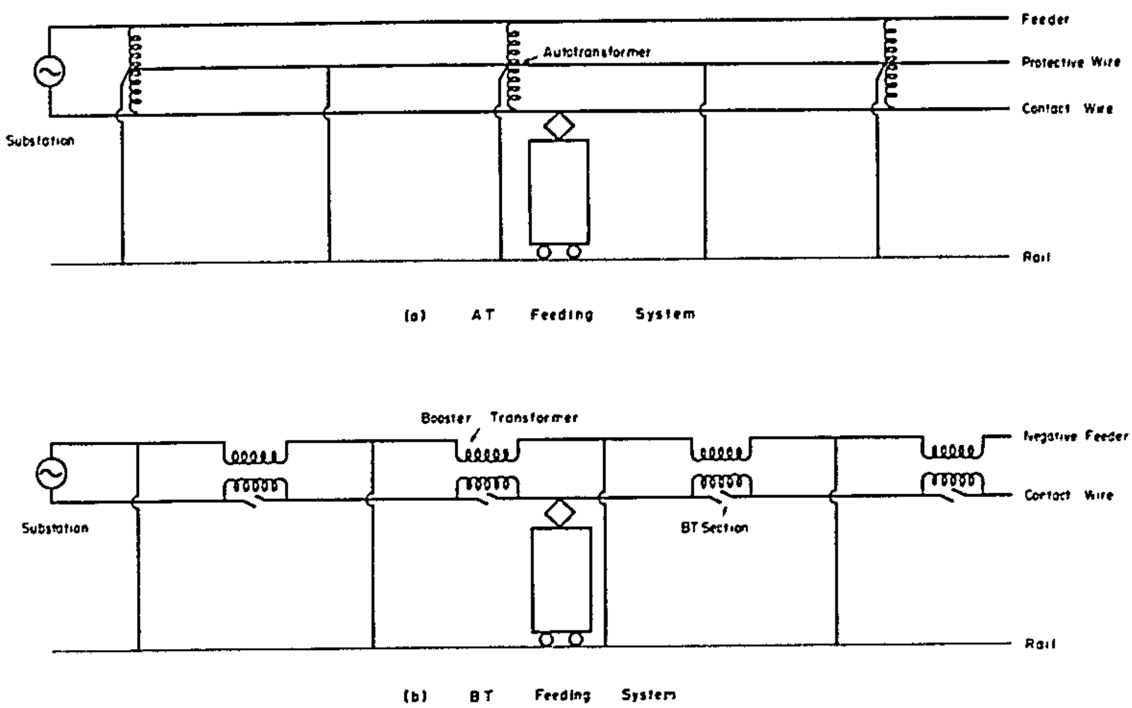


Fig. III-7-3 Comparison of AT and BT Feeding System

It is adequate for this suburban railway to adopt the AT feeding system for the following reasons:

(1) As the load current of electric cars is large, the feeding circuit must have a large current capacity.

(2) It is advantageous to raise the feeding voltage for reducing the voltage drop at the ends of the feeding circuit. This requirement can be satisfied by AT feeding system.

(3) The receiving of power from an electric power network with high reliability and large supply capacity signifies the receiving of electric power from high-voltage transmission network. In this case the location for receiving the electric power is restricted, and the AT feeding system is suitable because it permits long intervals between substations.

(4) The BT feeding system must be provided with BT sections in contact wires. When a pantograph passes through this BT section, arc will be generated. Particularly in case of large load current, the arc may damage the contact wire and break it in the worst case. The AT feeding system is characterized by nonexistence of such section.

7-5-2 Formation of Feeding System

The important thing in planning AC feeding system is the measures for decreasing the voltage unbalance. The balancing measures by 2-phase loading are applied to the feeding transformer described in Section 7-4-2. There are two ways of dividing the loads into 2-phase loading. The one is the method of feeding power upward and downward separately as shown in Figure III-7-4 (a), and the other is the method of feeding power by up and down lines separately as shown in Figure III-7-4 (b). The former is called the Feeding System of Different Phase at Direction and is suitable to track sections with many crossovers between up and down lines. The latter is called the Feeding System of Different Phase at Up or Down Line and is applied to sections in which the reduction in number of dead section is needed at main tracks though dead sections are required in crossover area between up and down lines. In the JNR, the Feeding System of Different Phase at Direction is generally adopted as standard.

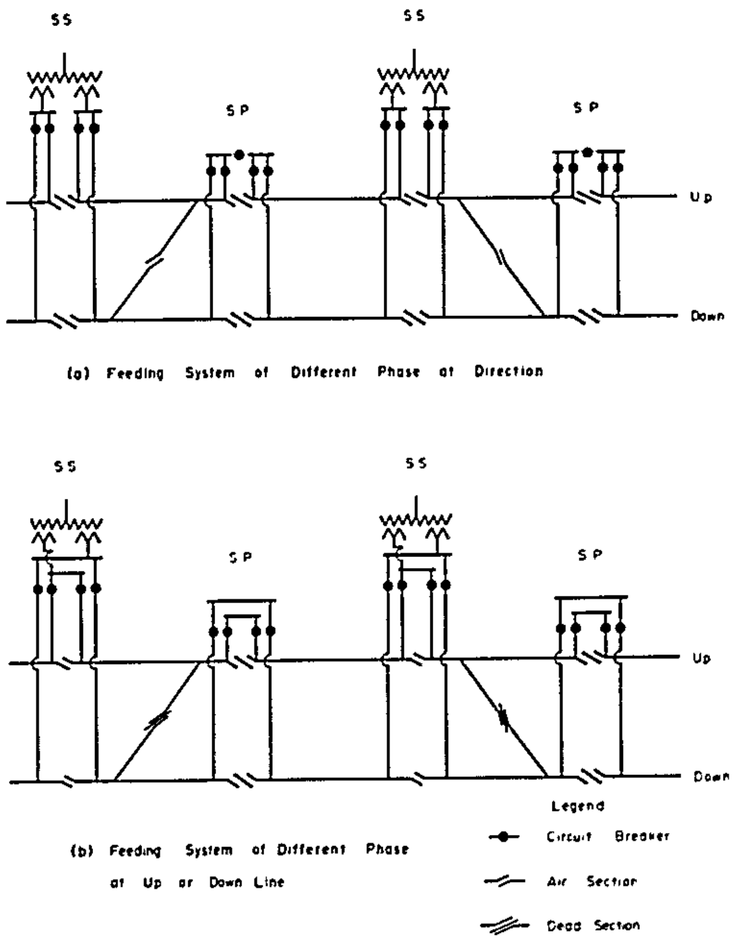


Fig. III-7-4 Feeding System

Suited to this suburban railway is the Feeding System of Different Phase at Direction, in which the feeder sections must be separated near the substation to balance M-phase and T-phase loads of the Scott connection transformer. The contact wires in this separating area need to be provided with a dead section at a place selected in a manner to permit the train passage always in coasting.

This suburban railway has such difficulties as (1) short distances between stations, (2) long-time powering operation, (3) train length to be taken as 300 m for future 12-car train operation, (4) frequent train stop resulting from a train standing in the way ahead, characteristic of a commuter service, and so on. These difficulties request detailed survey for deciding the dead section location. Yet the approximate location will be as shown in Figure III-7-5.

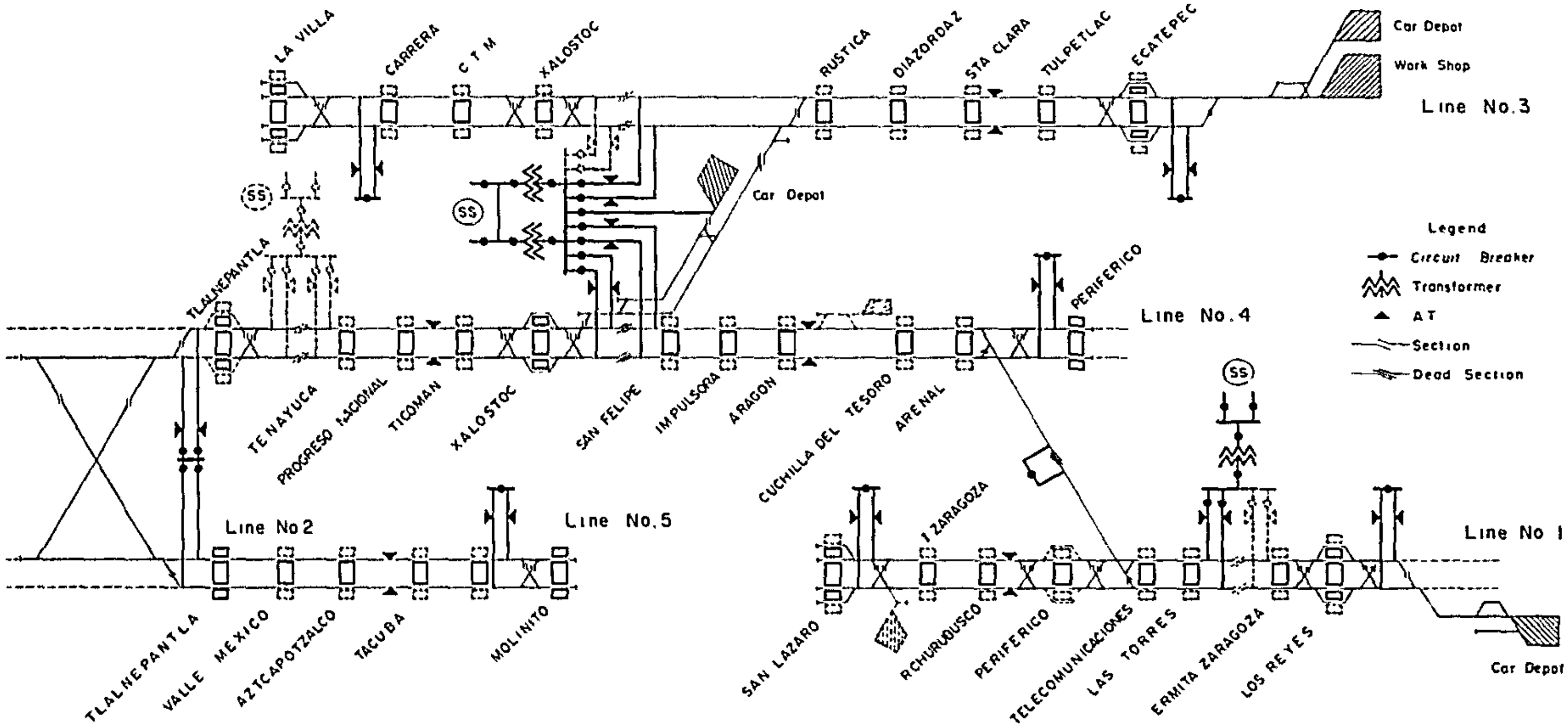


Fig. III-7-5 Feeding System Diagram

7-5-3 *Supporting Structure and Impedance of Feeding Circuits*

In this suburban railway it is needed, even with the adoption of AT feeding system, to lower the impedance in the feeding circuits and reduce the influence of voltage drop. It is also needed to review the current capacity of feeding circuits near a substation. For these reasons, the messenger wire shall be of concentric-lay-stranded copper and copper-clad steel composite conductor. This messenger wire is composed of stranded copper-clad steel wires at its center, which serves mainly to support tension, and the copper part around the circumference, through which current passes, as shown in Figure III-7-6. Such wires are used in some of the Japanese private railways and are very effective in lowering the impedance of the feeding circuits.

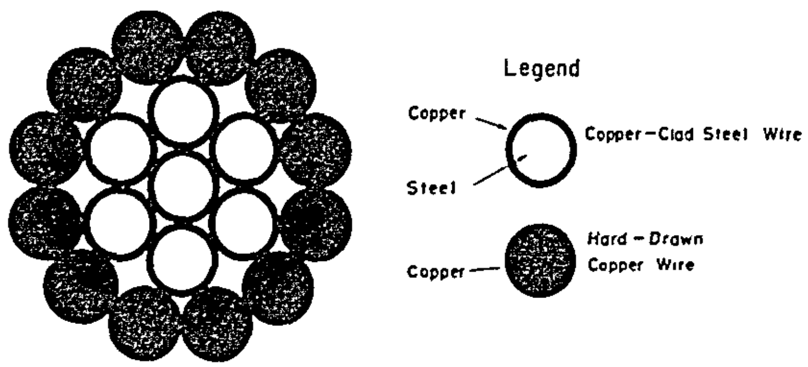


Fig. III-7-6 Concentric-Lay-Stranded Copper-Clad Steel Composite Conductors

The standard supporting structure of catenary system is shown in Figure III-7-7.

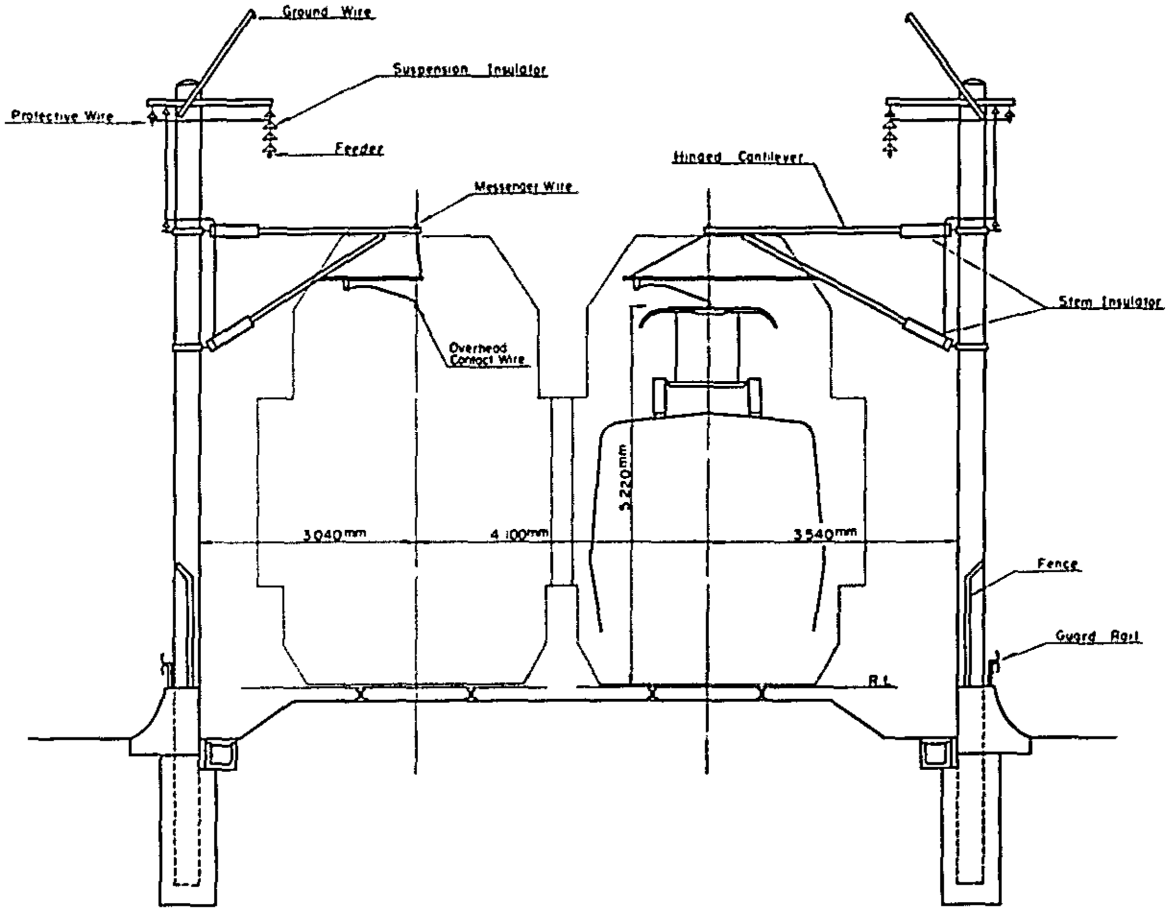


Fig. III-7-7 Standard Supporting Structure of Catenary System

7-5-4 Protection System

The loads of the feeding circuits are characterized by many moving loads great temporal variation in load current. The feeding voltage has a larger permissible range of fluctuation than that of other transmission and distribution lines, and a large electric power is supplied through the feeding circuits compared with its voltage. The feeding circuits include grounded rails, and the short-circuit accidents between rail and contact wire occur with a considerable frequency. These points make the selection of protection system difficult, and further there is another difficulty that in the AT feeding system the impedance from substation side may change, depending upon the location of short-circuit point between contact wire and rail.

As the protection system in AT feeding system in JNR, the methods are applied with a proper combination as described below. Against the short-circuit troubles in feeding circuits and dead earth troubles within vehicle, distance relays are used as main protection, and AC ΔI-type relays as backup protection. In some sections, low-voltage relays, or ΔE-type relays and interlinked circuit breakers etc. are used together, to ensure the detection of troubles.

The protective wires to be provided in the feeding circuits are a device which serves for sure detection and protection in the substations at the time of dielectric breakdown of insulators and dead earth troubles in the feeding circuits.

In this feeding circuit will be adopted the circuit braker reclosing system. In the actual service results in JNR, the reclosing system has eliminated 70 to 80 % of troubles which would cause confusion of train operation. The reclosing time, as planned, is 0.5 sec. standard in JNR.

The locating of the point of trouble is efficient for early recovery, in case where any trouble happens in a feeding circuit. The AT feeding system has so complicated circuits that it is difficult to locate the point of trouble merely on a basis of impedance. The JNR has developed AT neutral current ratio type fault locators and put them into practical use with a good success.

7-6 Overhead Catenary System

7-6-1 Catenary System in Crossovers

In this suburban railway, simple catenary system is planned for main tracks, and direct suspension system for others. The direct suspension, however, is subjected to a larger uplift and a large dip in comparison with simple catenary. Therefore, it is desirable to use simple catenary in crossovers.

7-6-2 Standard Catenary System

The standard catenary system in the simple catenary sections of the main tracks is as described below.

Concentric-lay-stranded copper and copper-clad steel composite conductors of the order of 120 mm^2 or more are used for messenger wires as mentioned in Section 7-5-3, and grooved hard-drawn copper contact wires (GT) of 170 mm^2 are used for contact wires with consideration to current capacity in power collection.

The types and sizes of feeder lines and protective wires are decided mainly on a current capacity basis. As a result of review, the planning has been made with hard-drawn stranded aluminium conductors (H-Al) of 300 mm^2 for the former and of 100 mm^2 for the latter.

Overhead ground wires are to be provided on the poles on both sides of railway track to alleviate damage by lightning.

The foundations for poles in the catenary system are preferably to be constructed together with the civil work, and these poles cannot be designed without detailed survey on the nature and strength of the soil. For this reason, no description is given in this respect.

7-6-3 Automatic Tensioning Device

From the viewpoint of current collecting features, automatic tensioning devices should preferably be provided in the catenary system related to high speed train operation. Detailed survey will be needed on the range of change in atmospheric temperature and temperature rise by direct sunlight or electric current, at the stage of practical construction design and engineering work. According to statistic data from 1941 to 1970 on Mexico City, the maximum atmospheric temperature was 32.8°C, and the lowest was -4.4°C. This represents a more favorable condition than the JNR standard design temperature of 40°C to -10°C. This shows that sufficient tension adjustment will be practicable.

In JNR, pulley type automatic tensioning devices as illustrated in Figure III-7-8 are specified as standard and are installed, one for each section of 1,500 to 1,600 m in length. Oil pressure type automatic tensioning device was once put into practical use, but was abandoned because of oil leakage easily caused in long-time use and the difficulty in taking preventive measures.

7-7 Electric Power Facilities for Lighting

7-7-1 Electric Power Facilities in Stations

Electric power needed for station is to be used mainly for lighting of concourse, offices, staircases etc., as power for ticket vending and examining equipment and escalators, and as power sources for signal and telecommunication systems. For such power supply, there can be considered in general the receiving of power from general power distribution system and traction substation. Since Mexico City is provided with 23 kV distribution lines at various places, the receiving of power from such distribution line is most reasonable. In the areas without such distribution line or near traction substations, there can be considered the installation of distribution lines for railway's exclusive use along the railway track. Detailed field survey and comprehensive judgement are required to decide what system should be adopted for individual stations.

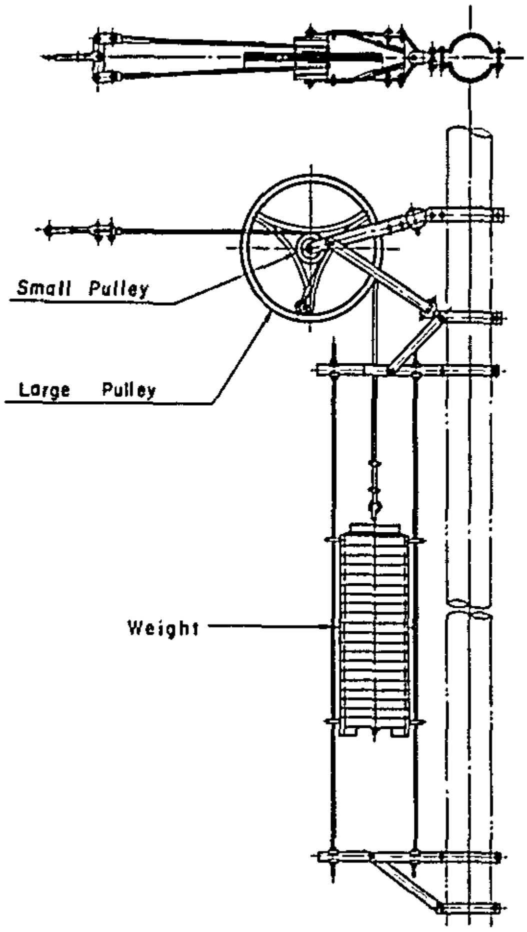


Fig. III-7-8 Automatic Tensioning Device

7-7-2 Measures to be taken at time of Power Source Failure

Among the station power facilities, the facilities whose breakdown is not permissible are those of lamp illumination and equipment which are the minimum requisite for train operation and passenger service.

There are following systems as their standby power sources:

(1) 23 kV distribution line of a different power source system

(2) Distribution line from traction substation

(3) Receiving of power from feeding system

(4) Installation of emergency generating set

The actual application out of these systems is to be determined by survey of individual stations, but as a general concept the system (3) is for intermediate stations, and the system (1) or (4) for principal stations. The system (2) can be considered for stations near substations for electrical operation. In case where the feeding system is used as reserve power source, the installation of automatic voltage regulators is to be reviewed, because the voltage fluctuates so much.

7-8 Maintenance System and Organization

Such systems as substations and catenary system are so new that greatest laborsaving can be expected.

The maintenance of the field equipment is to be assigned to the charge of trackside maintenance personnel. The maintenance is carried out by combinations of the method of confirming the functions at regular intervals and performing the necessary repairs, method of replacing parts, method of taking measures in advance of troubles through constant supervision of functions, and method of replacing parts after troubles have been caused.

In JNR, organizations for maintenance are determined with consideration to the ranges of charges restricted by management factors, and the number of personnel required for emergency recovery in case of accident and the time needed for reaching the accident site and through review on individual cases. Also in this suburban railway, the similar concept will apply to its organization for maintenance.

8. Signal and Telecommunication Facilities

8-1 Outline of the System

8-1-1 Concept of System Design

The requirements of this project exist in the safe, accurate and swift transportation of a great many passengers. To satisfy these requirements, such signal and telecommunication system should be adopted as will be best suited to this project and economical at the same time, taking the following points into due consideration:

(1) Securing of Safety

Introduce such equipment as will have the function of securing the safe train operation, and perform the system design, equipment design and component parts selection in which the concept of fail safe is incorporated that the equipment may act toward the safe side even if it should get out of order.

(2) Unification of Transport Control

The facilities should be such the train movement in each line is grasped at the Control Center in a manner that the normal train operation may be secured, and that any disorder in train schedule may be put to a prompt regularization.

(3) Consideration in System Reliability

To minimize the disorder in train schedule because of equipment failure, due consideration should be given to the design and manufacture of equipment and the selection of component parts to make the facilities of high reliability.

(4) Simplification of Maintenance

To facilitate the maintenance, the equipments requiring inspections should be centralized as much as possible, and the reduction in recovery time from failure should be adopted using unit-replacement system. Further, such system as will supervise the principal equipment should be installed so that prompt actions may be taken against any abnormality.

(5) Insulation Coordination

Insulation coordination with the relative facilities should be intended that the damage or injury may not be given by dead earth accident.

(6) Expansibility of the System

The system should be such that has expansibility so as to correspond to future increase in demands, improvement plan, etc.

8-1-2 System Constitution

Principal facilities which form the system are as follows: (Refer to Figure III-8-1, Figure III-8-2 and Table III-8-1.)

(1) Train Operation Security Facilities

This is the facilities for high-speed, high-efficiency and safe train operation, including Automatic Train Control Equipment (ATC), Automatic Train Operation Equipment (ATO), Relay Interlocking Equipment, etc.

(2) Dispatching Facilities

This is the facilities for smooth and high-efficiency transportation, including Total Train Control Equipment (TTC), Train Radio Equipment, Dispatch Telephone Equipment, Facsimile, etc.

(3) Information Transmission Facilities

This is the facilities for giving and receiving various types of information necessary for performing transportation services, including Carrier Telephone Equipment, Telephone Exchange, Telephone Set, etc.

(4) Other Facilities

These are facilities which supplement the functions of each of the facilities mentioned above, including Provisional Speed Restriction Device, Emergency Train Stop Device, Disaster and Track Interference Detector, Passenger Monitoring Device, Passenger Service Device, Wayside and Yard Operators Communication Device, Principal Equipment Supervising Device, etc.

8-2 Function of Each Equipment and Its Outline

8-2-1 Automatic Train Control Equipment (ATC)

(1) Functions

The ATC has the function of continuously representing in the cab the signals indicating the permissible train operating speeds as decided by the distance to the preceeding train and the route conditions (e.g. running direction, maximum speed, speed restriction at curves and turnouts, etc.), and of automatically lowering the train speed in

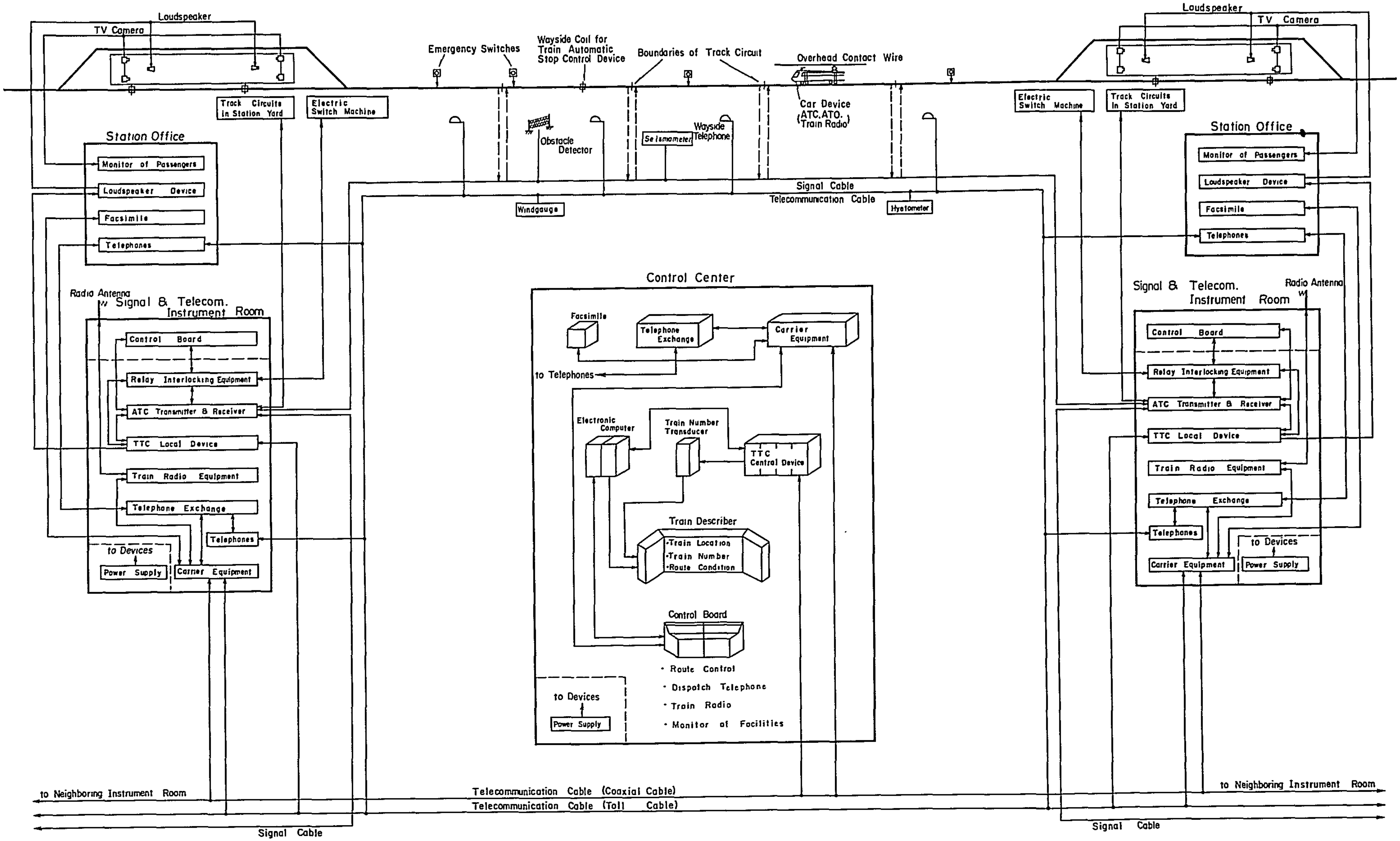


Fig. III-8-1 System Diagram of Signal and Telecommunication

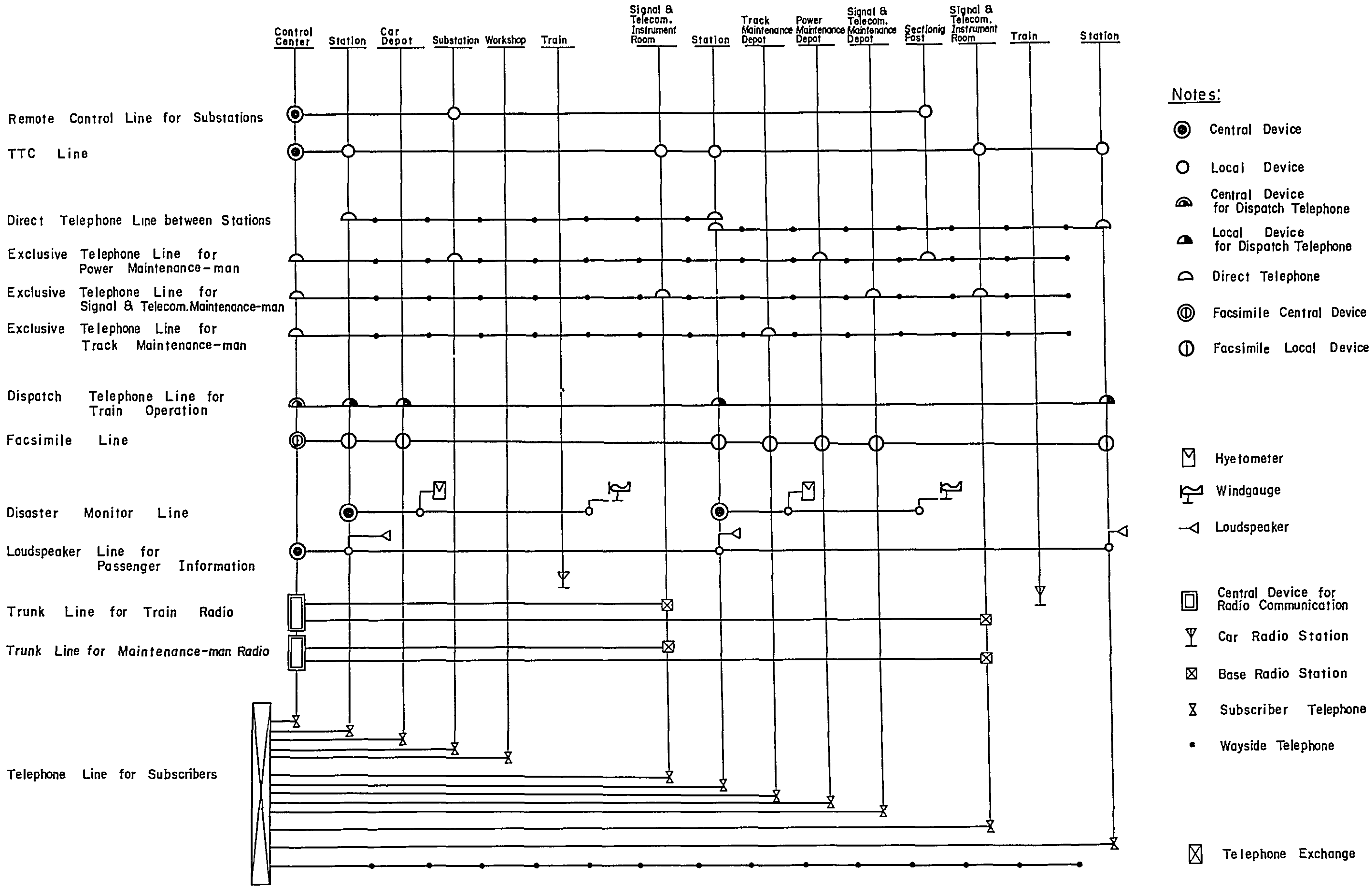
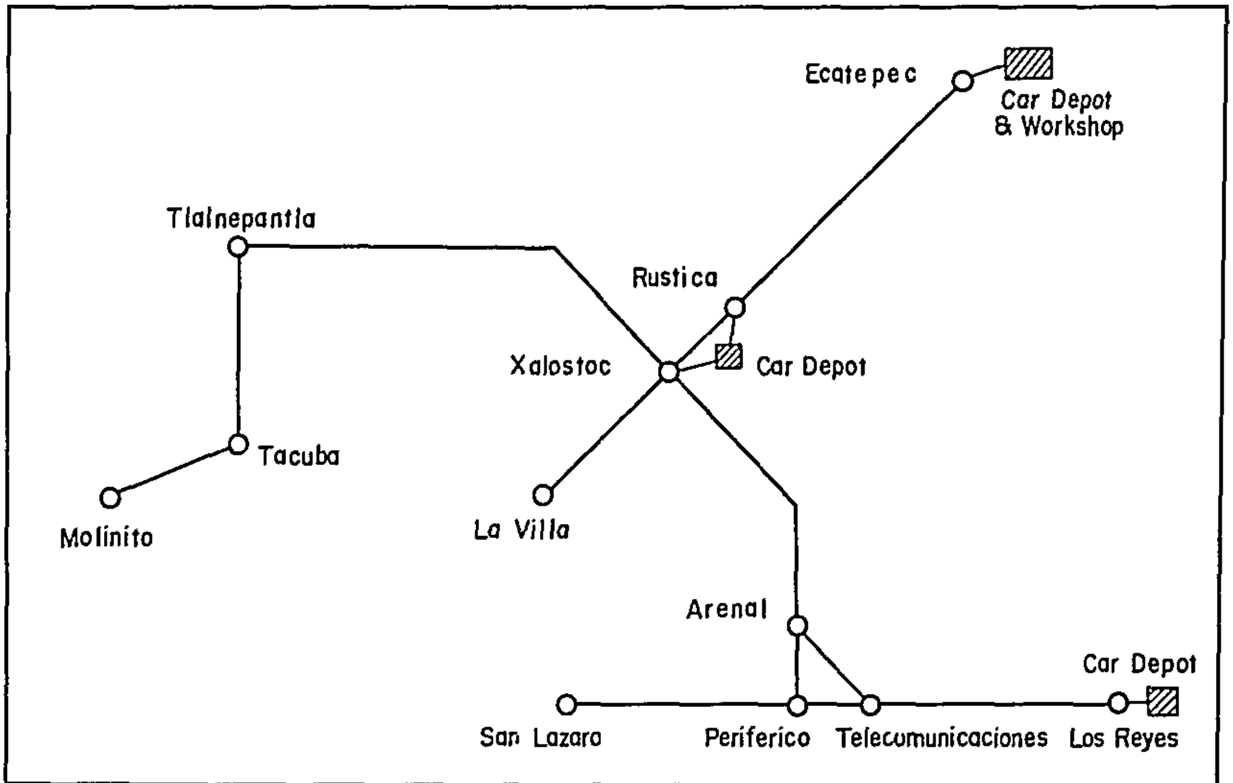


Fig. III-8-2 Plan Diagram of Telecommunication Channel

Table III-8-1 Location of Facilities



Facilities \ Stations	San Lazaro (Control Center)	Periferico	Telecomunicaciones	Los Reyes	Car Depot at Los Reyes	Arenal	Xalostoc	Car Depot at Xalostoc	La Villa	Rustica	Ecatepec	Car Depot & Workshop at Ecatepec	Tlalnepantla	Molinito
TTC Central Device	O													
Relay Interlocking Equip. & TTC Local Device	O	O	O	O	O	O	O	O	O	O	O	O	O	O
ATC Equipment	O	O		O			O				O		O	O
Base Station for Train Radio		O		O			O				O		O	O
Telephone Exchange	O				O		O					O	O	
Coaxial Carrier Equipment	O	O			O		O					O	O	
PCM Carrier Equipment							O		O				O	O
Base Station for Maintenance-man Radio		O					O				O		O	

conformity with that signal aspect. (Refer to Figure III-8-3.)

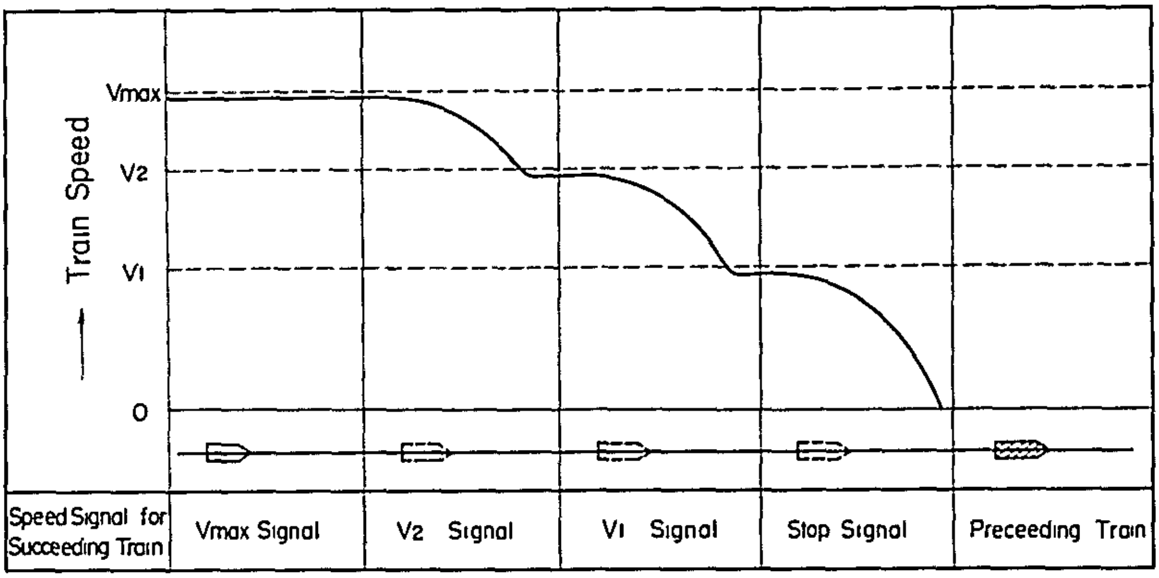


Fig. III-8-3 An Example of Run-Curve by ATC Operation

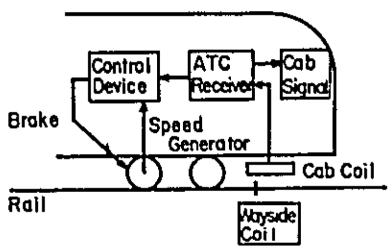
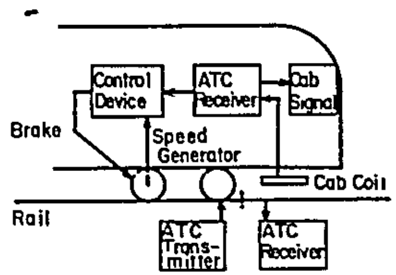
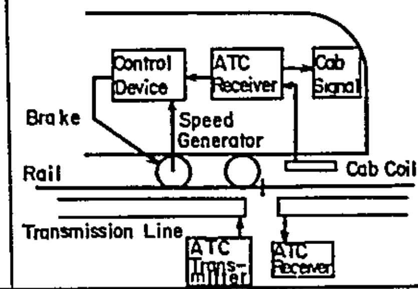
(2) Transmission System of Train Control Information

Train control information is transmitted from wayside to train in the form of speed signal current. The train running speed for each block is decided in accordance with the location of the preceeding train and the route conditions. Various transmission systems can be considered for this case, but the track circuit system is recommended in this Project. (Refer to Table III-8-2)

The above-mentioned block length decides the maximum transport capacity and therefore the track must be divided into such blocks in a manner to permit a train to run freely without any speed restriction by its preceeding train so far as the train is operated on schedule in conformity with the train diagram.

The decision of block length, therefore, must be performed after the determination of the fundamental elements such as train running curves between stations, stop time at stations, step of speed signals, the maximum train length, acceleration and deceleration rate of train, idling time from the receiving of signal to the actual brake application, etc. For this Project, the system is to be designed in a manner to permit a headway of 2 minutes 30 seconds for the present.

Table III-8-2 Comparative Table of Train Control System

Item		Intermittent Control Principle	Continuous Control Principle (Track Circuit)	Continuous Control Principl (Transmission Line along the Track)
System Composition				
Safety	Fail Safe	X	O	O
	Emergency Protection	X	O	O
Efficiency	Information Capacity	△	O	O
	Reaction Time to the Signal Change	X	O	O
Reliability		X	O	△
Simplicity of Maintenance		O	△	△
Expansibility	Headway Shortening	O	△	△
	ATO	X	O	O
Disturbance to Track Maintenance Work		△	O	X
Train Detection		Another devices are required	Track circuits are used in common	Another devices are required
Construction Cost	ATC Cab Device	About the same		
	ATC Wayside Device	O	△	X
	Total System	O	O	X
Estimation		Advantageous in the point of maintenance and economy but inferior in the point of safety and efficiency. For this, not suitable for commuter line.	Advantageous in many points and the most suitable type for this project.	This type is less advantageous. The reasons are, (1) transmission lines laid along the track hinder track maintenance work and (2) another devices are required for train detection. But, advantageous for rubber-tire transportation system where track circuit is not available.

Notes : X Good , △ Better , O Best

(3) Outline of the Equipment (Refer to Figure III-8-4.)

1) Wayside device

The signal current sent to each track circuit conforming to the train position and the route conditions will be generated by the device put in the instrument room as shown in Table III-8-1. For this signal current we recommend the power source synchronizing AM-SSB system use-proven in the Japanese Shinkansen so as not to be affected by traction current supposed to be max. 800 amperes.

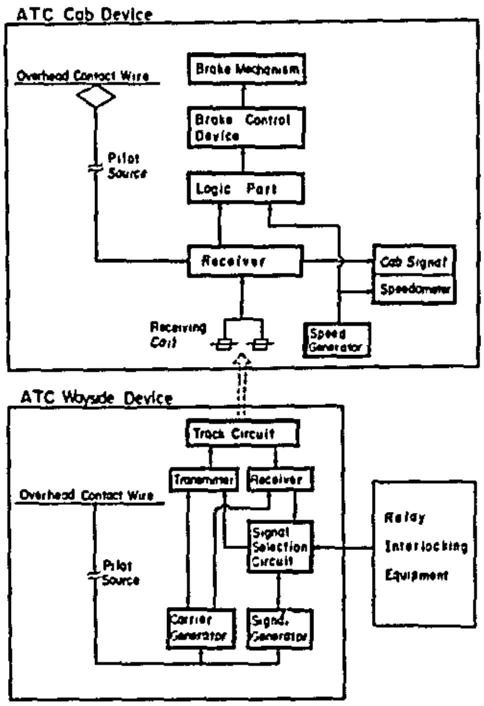


Fig. III-8-4 Block Diagram of ATC Equipment

The track circuit is used for signal current transmission line and for train detection. The instrument room and each track circuit are connected together by aluminium-sheathed signal cables to transmit signal current.

2) Cab device

The signal current flowing in the track is picked up by a receiving coil and translated into speed signal by on-cab receiver. The speed signal will be indicated on the cab signal. At the same time the braking comand is emitted for deceleration in case where the train speed is higher than the indicated on the signal. In case of stop signal, the braking will not be released until it is turned to the signal indicating the proceed.

In case of failure in ATC or running in a car depot or workshop, the train is to be operated with the care of the train driver himself, after limiting the maximum permissible speed to 20 to 30 km/h by operating a cab switch.

8-2-2 Automatic Train Operation Equipment (ATO)

(1) Functions

ATO has the function to automatically start and accelerate the train on condition of closing of the doors, perform automatic running within ATC speed limits and automatically stop the train at a prescribed position of the platform.

(2) Outline of the Equipment

ATO has on-the-train automatic devices for train acceleration, speed control and train stop at station, thus permitting automatic train operation without need of manual operation by train driver. Details are given in Article 9.

Wayside coils are installed at required positions to give to the cab the train automatic stop control information.

8-2-3 Relay Interlocking Equipment

(1) Functions

In the station yard with turnouts, the switches are operated to set up the route and then are locked. Further, after confirming that the route is not occupied by another train or vehicle, permission is given to the train for the entrance to that route. Thus the Relay Interlocking Equipment has the function of securing the safe train operation by setting the interlocking between the related equipments, one with another, through electric circuit with relays.

(2) Outline of the Equipment

This equipment is composed of the control panel for handling the setting up of the route, a group of relays for locking or interlocking the related devices, the electric switch for changing over the turnouts, the train detecting track circuit, signal cables for connecting various devices together, etc. The car depots and workshop need wayside signals besides those mentioned above, for manual train operation by train driver. The track circuit is also used as ATC signal transmission line.

The route setting at each station is ordinarily performed by TTC (described later), but when necessary as in abnormal condition, it can be controlled at individual station. In car depots and workshop, however, it is always handled at respective local control boards.

8-2-4 Total Train Control Equipment (TTC)

(1) Functions

TTC has the functions to secure the normal train movements and, in case of any abnormality, attempt an early normalization through swift and proper measures, by means of displaying the train locations at the Control Center and at the same time permitting the route control and the instruction of departure time at each station to be made also from the Control Center.

(2) Outline of the Equipment

The Control Center at San Lazaro will be equipped with a control board and a display board. The control board will have levers for setting up the route at each station, sutomatically or manually operated changeover switches, etc. The display board will have the whole track layout drawn on it, and exhibit there the track circuits in which trains exist, train numbers, situations of routes, the directions in which the switches are closed, etc., by means of lamp indications.

The Control Center and each instrument room are to be equipped with such equipment as will transmit the control and display information, and a high-speed information transmission of 2,000 bauds or more will be needed for commuter train services having a great amount information to be processed.

Each piece of information, when transmitted, is to be converted to the digital codes, i.e. pair pulse codes of high reliability.

In ordinary case the control board is operated automatically by computer. The indication of departure time, alarm for departure, indication of time of delay, train operating records, etc., are also controlled by computer. In case of disorder in train schedule or failure in computer, the operation is manually performed by the dispatching personnel.

8-2-5 Train Radio Equipment

(1) Functions

Train radio has the function of permitting the dispatching personnel at Control Center and the train driver to have a direct conversation for the exchange of information, as required by the need for modification of the basic train schedule and by the occurrence of accident.

(2) Outline of the Equipment

The train radio systems are classified broadly into the inductive radio system, which connect a catenary or a wire extending along the track closely with on-vehicle antenna, and the space wave radio system, which utilizes VHF or UHF waves. The former will have too much noise in AC electrified lines and is improper for use in this Project. Thus the latter is to be used. The frequency band to be used is a 400 MHz band from the viewpoint of the securing of the wave to be used, reduction of blind zones, miniaturization of the equipment, etc.

Two waves will be allotted to each line to avoid intermodulation. The talking system is semi-duplex type composed of the simultaneous talking and hearing for dispatching personnel and the "press and talk" for train drivers, to be operated in a manner that the dispatcher calls a train by the train number and that a call signal is given to the dispatcher when a driver takes up his telephone.

The base station is to be installed at a place shown in Figure III-8-5 to make the communication possible over all the lines. Yet for details, the location of the base station needs to be determined based on radio wave propagation tests. If there is a place where radio wave is geographically difficult to reach, proper countermeasures against weak radio field should be taken by the use of leaky coaxial cables, boosters, etc. The tunnel connecting the Lines Nos. 1 and 4, however, will not be given such countermeasures against weak radio field, as this tunnel is only for out-of-service trains.

As to the radio waves to be used, it is needed to secure the waves for exclusive use to avoid the possibility of radio interference.

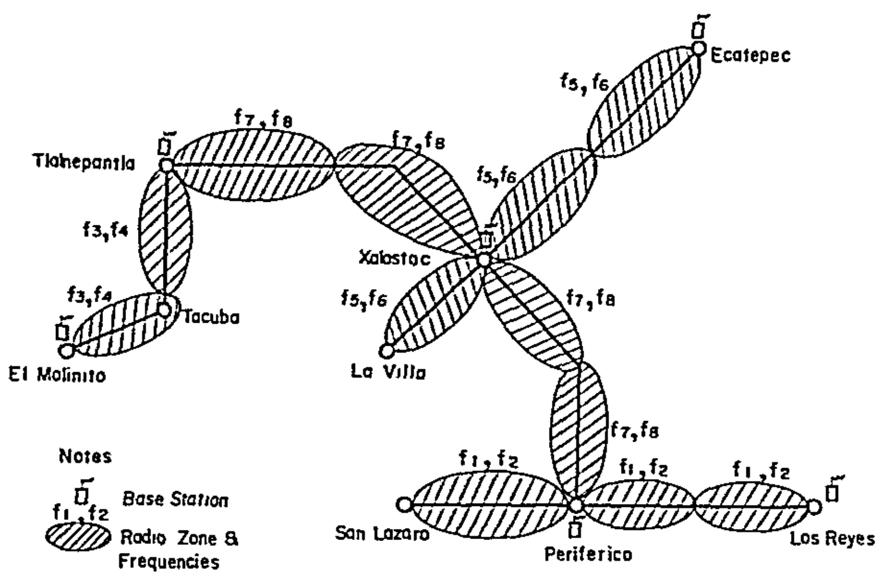


Fig. III-8-5 Location of Base Stations for Train Radio

8-2-6 Dispatch Telephone Equipment and Facsimile

(1) Functions

Dispatch telephone and Facsimile have the functions to permit the direct exchange of information between the dispatching personnel at the Control Center and the personnel at stations, maintenance depots, etc., as required by the need for modification from the basic train schedule and by the occurrence of accident, etc.

(2) Outline of the Equipment

1) Dispatch telephone equipment

Master telephone at Control Center and local telephones at various service organizations are connected by direct circuits and not through telephone exchange, capable of meeting the emergency needs. The calling is of frequency selection type, capable of individual and general callings.

2) Facsimile

This is an equipment used for exchange of the information in writing or drawing, so to speak a simplified phototelegraphic system.

8-2-7 Carrier Telephone Equipment

(1) Functions

Suppose that two regions have each a great many subscribers and that communications are made among these subscribers, then vast and complicated circuits will be necessary. The simplification of these circuits can be made by using the telephone exchange as mentioned in the next section for communication within each range and using carrier telephone system for communication between the regions.

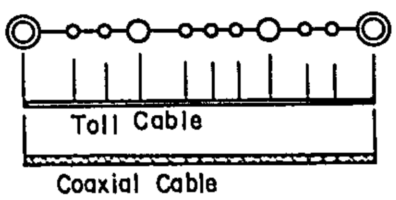
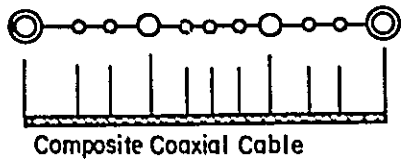
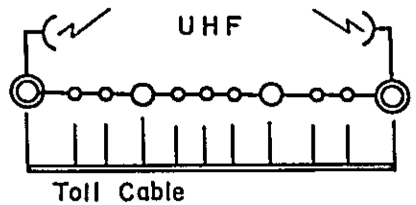
The carrier telephone system has the function of performing the multiplex transmission to save the number of wires.

(2) Transmission Lines

Various kinds of information to be used in railroad services are generated everywhere along the line. From the viewpoint of transmission of such information, classification is made roughly to short-distance and long-distance transmissions. The former is called the local channels, and the latter the trunk channels.

Various systems can be considered as transmission lines, and the Table III-8-3 shows the comparison of 3 representative systems. It is

Table III-8-3 Comparative Table of Information System

Item \ System		Coaxial Cable + Toll Cable		Composite Coaxial Cable		UHF Radio + Toll Cable	
System Composition (◎ : Main Station, ○ : Local Station, o : Wayside Point, ⊥ : Cable Branch)							
Channel Classification	Main Station – Main Station	Coaxial Cable	Coaxial Carrier Channel	Composite Coaxial Cable	Coaxial Carrier Channel	UHF Radio	UHF Radio Channel
	Local Station – Local Station Main Station – Local Station	Toll Cable	PCM Carrier Channel		PCM Carrier Channel	Toll Cable	PCM Carrier Channel
	Others		Voice Channel		Voice Channel		Voice Channel
Channel Capacity		○		△		X	
Simplicity of Maintenance		○		○		△	
Simplicity of Construction Works		○		X		△	
Reliability		○		X		△	
Expansibility	Channel Increase	About the same					
	Line Extension	△		X		○	
Transmission Hindrance		○		○		X	
Construction Cost		X		△		○	
Estimation		The construction cost becomes rather high but stabilized transmission can be expected. The most suitable type for this project.		Execution of cable– blanching works is rather complicated and reliability can possibly be lowered.		Not recommended in metropolitan areas because UHF system requires an exclusive use of certain frequency ranges and there is a large possibility of its propagation routes being hindered.	

Notes : X Good , △ Better , ○ Best

recommended to use, in this Project, toll cables for local channels, and coaxial cable for trunk channels, with due consideration to the future plan.

(3) Outline of the Equipment

The local channel is composed mainly of voice channels, with PCM carrier channel added between local stations, one with the other, and between local station and main station. PCM carrier telephone equipment contains 30 channels, with repeaters inserted at about 2 km intervals.

Toll cables are to be installed over the whole line.

Trunk channels form junction circuits between main stations, using coaxial carrier telephone equipment for 120 channels, with repeaters provided at about 12 km intervals. A coaxial cable is to be installed along the whole line of Lines Nos. 1 and 4, and between Xalostoc and Ecatepec of the Line No. 3.

8-2-8 Telephone Exchange

(1) Functions

A telephone exchange has the function to call up a subscriber by selecting and connecting the circuit of the subscriber automatically in response to the calling by another subscriber to the same telephone exchange.

Similarly subscribers to another telephone exchange can be called up.

(2) Outline of the Equipment

Crossbar type telephone exchanges provided with relays have been popularized, but recently the electronic telephone exchanges provided with semiconductors instead of relays have been developed. These have no such moving contacts as relays to be improved in reliability and simplified in maintenance features. Furthermore, they have great merit such as fast processing speed enabling practicability of digital code transmission, easy addition or alteration of service functions, miniaturization of equipment resulting in smaller floor area needed, easy construction work new or enlarging, and no noise generated. For these reasons, electronic telephone exchanges are recommended for this Project, though the initial investment may be a little higher.

300-line telephone exchanges are to be installed at the places shown in Table III-8-1.

Telephone sets will be of "push button" type, to be distributed in each service organization.

Telephone number planning and junction line configuration should be worked out with sufficient consideration to the total plan as a whole.

8-2-9 Provisional Speed Restriction Device

Sometimes slowed-down train operation is compelled by disaster, improvement work, maintenance work, etc., on a temporary basis. This is the device which lowers the maximum permissible speed at such sections down to the slow running speed, with the corresponding control board and accessory circuits to the ATC system.

8-2-10 Emergency Train Stop Device

This device is to be used when wayside operating personnel find out failure in rail, obstacles on the track, etc., and intend to stop trains urgently. Switches are provided at about 100 meter intervals along the track, and by pushing such switch the ATC stop signals are sent to the related track circuits.

8-2-11 Disaster and Track Interference Detector

(1) Wind Speed and Rainfall Monitoring Device

In case of heavy wind or rainfall, it is needed to stop the train operation or limit the train speeds. Windgauges and hyetometers are therefore installed at required places, and warning is given to the Control Center in case where the prescribed values are exceeded.

(2) Earthquake Sensor

In case of a big earthquake the trains must be stopped immediately. Seismometers are therefore installed at required places and send out ATC stop signals when the prescribed values have been exceeded.

(3) Obstacle Detector

At the places where rocks or automobiles may fall on the track from geographical viewpoint, the sensing wires should be stretched. If such wire is broken, ATC stop signal is sent out for protection purposes.

8-2-12 Passenger Monitoring Device

To monitor the movements of passengers at platforms, wickets, etc., there will be installed cameras at main places and video display units in a station office.

8-2-13 Passenger Service Device

(1) Loudspeaker for Passenger Information

This is the device to announce the train departure, arrival, platform number, access, destination, etc., in which ordinary announcement is recorded on magnetic tape and is controlled automatically by TTC. Station personnel, dispatching officers, etc., may speak as required by the case.

(2) Clocks

Electric clocks will be installed at required places.

8-2-14 Wayside and Yard Operators Communication Device

(1) Wayside Telephone Sets

These are to be used by personnel who are engaged in wayside operations to communicate information, and will be installed at about 500 meter intervals. The system will cover the channels for telephone exchange subscribers, for exclusive use for train operation, electric power, signal & telecommunication, track maintenance, etc. The system is to be used by switching it to required lines.

(2) Radiotelephones for Wayside Operators

These are to be used for exchange of information among wayside operators, one with another, who work moving along the track or between the dispatching officer at Control Center and such wayside operator. Base stations are to be installed at the places shown in Table III-8-1.

(3) Radiotelephones for Yard Operators

These are to be used for mutual communication among shunting workers, signal men and train drivers in the shunting work in car depots and workshop.

8-2-15 Principal Facilities Supervising Device

The state of the principal facilities will be indicated on the control console in the Control Center so that abnormalities may be found early and be tackled swiftly. The site information is sent to the Control Center by use of the TTC transmission device.

8-2-16 Others

(1) Instrument Room

Dust proofing and moisture proofing should be considered for the instrument room.

The instrument room shall have signal and telecommunication equipments centralized as much as possible in it, so as to facilitate the maintenance work and the recovery from accident.

(2) Power Source

AC power source supplied from the electric power facilities will be the basic, but batteries will also be used for the important equipment as a standby.

(3) Cables

Signal and telecommunication cables will be metal sheathed cables for prevention of inductive distrubance, and will be, as a principle, laid under the ground at areas between stations and housed in concrete ducts within station yards.

(4) Fire Alarm Device and Automatic Fire Extinguisher

These are to be provided in important buildings, such as the Control Center.

8-3 Inductive Disturbance by the AC Electrification and Its Countermeasures

8-3-1 Inductive Disturbance

If the catenary and the telecommunication line run in parallel with each other in AC electrified section, there occur two phenomena: (1) Electrostatic induction in which a voltage is induced in communication line by means of electrostatic coupling between the two lines, and (2) Electromagnetic induction in which a voltage is induced in communication line by the difference between catenary current and ground leakage current. These induced voltages need to be given sufficient countermeasures because they may, in the form of noises, bring about interruption of telephonic communication and motion error of equipment, and may, in the form of dangerous voltage, lead to electric shock accident or burning loss of equipment.

Disturbance by electrostatic induction is not so big a problem, because shielded cables do not attract such induction and therefore, bare wires, most affected, are usually replaced by cables also as countermeasures against electromagnetic induction.

Electromagnetic induction includes the abnormal induction voltage caused by accidental current at the time of catenary dead earth, the normal induction voltage by traction current, and the induction noise voltage by harmonic wave component generated from substation or electric car. According to the recommendations by CCITT, the abnormal induction voltage is specified to be less than 430V, and the normal induction voltage to be less than 60V, for protection of human body and equipment. As for communication quality, induction noise voltage which is evaluated taking the sensitivity of human ear into consideration is specified to be less than 1mV (2.5mV for bare wires). The normal induction voltage is required to take the limit values competing the equipment performance for the prevention of motion errors of telephone exchanges.

8-3-2 Countermeasures

To reduce the induction voltage as much as possible, such measures are to be taken on the inducing side as will reduce rail-earth leakage of return current by the use of AT system in feeding circuit and will reduce higher harmonic component by the installation of filters on the vehicles.

On the induced side, the predictive calculation will be conducted on the induction voltage, and the telecommunication lines found to exceed the above-mentioned limit values are to be improved. In this case, facilities outside the railway, such as public telecommunication lines, are customarily improved by the respective organizations, and the expenses are borne by the railway.

There are needed for the predictive calculation a vast amount of data such as distance between railway and telecommunication lines, telecommunication line types and state of installation, performance characteristics of such equipment as telephone exchange, earth conductivity, electric power feeding system, load current and accident current, etc. Furthermore the calculation itself is very complicated, and the use of electronic computers is required.

The considerable methods of improvement include the use of cables sheathed with metal such as aluminium, housing of cables in metal conduit tubes, and the insertion of repeating coil to divide the circuit lines or improve the balance factors in such lines. It will be needed in this Project to review the countermeasures for the public communication lines (mainly cables) located principally within 500 meters or so along the railway track and for the communication lines of the National Railways of Mexico (mainly bare wires).

8-4 Concept of Maintenance Work

Signal and telecommunication facilities exist throughout the whole line, and these individual facilities are organized into a system with the objective of safe, accurate and swift mass transportation. For their normal functioning, therefore, it is necessary to manage them individually and also as a whole system.

The personnel engaged in maintenance need to be given sufficient theoretical education and practical training on system configuration, principle of motion and functioning of each equipment, inspection methods and method of recovery from accident. It is essential to prepare and make available the data of equipment, maintenance manuals, etc.

8-4-1 Central Dispatcher (System Control)

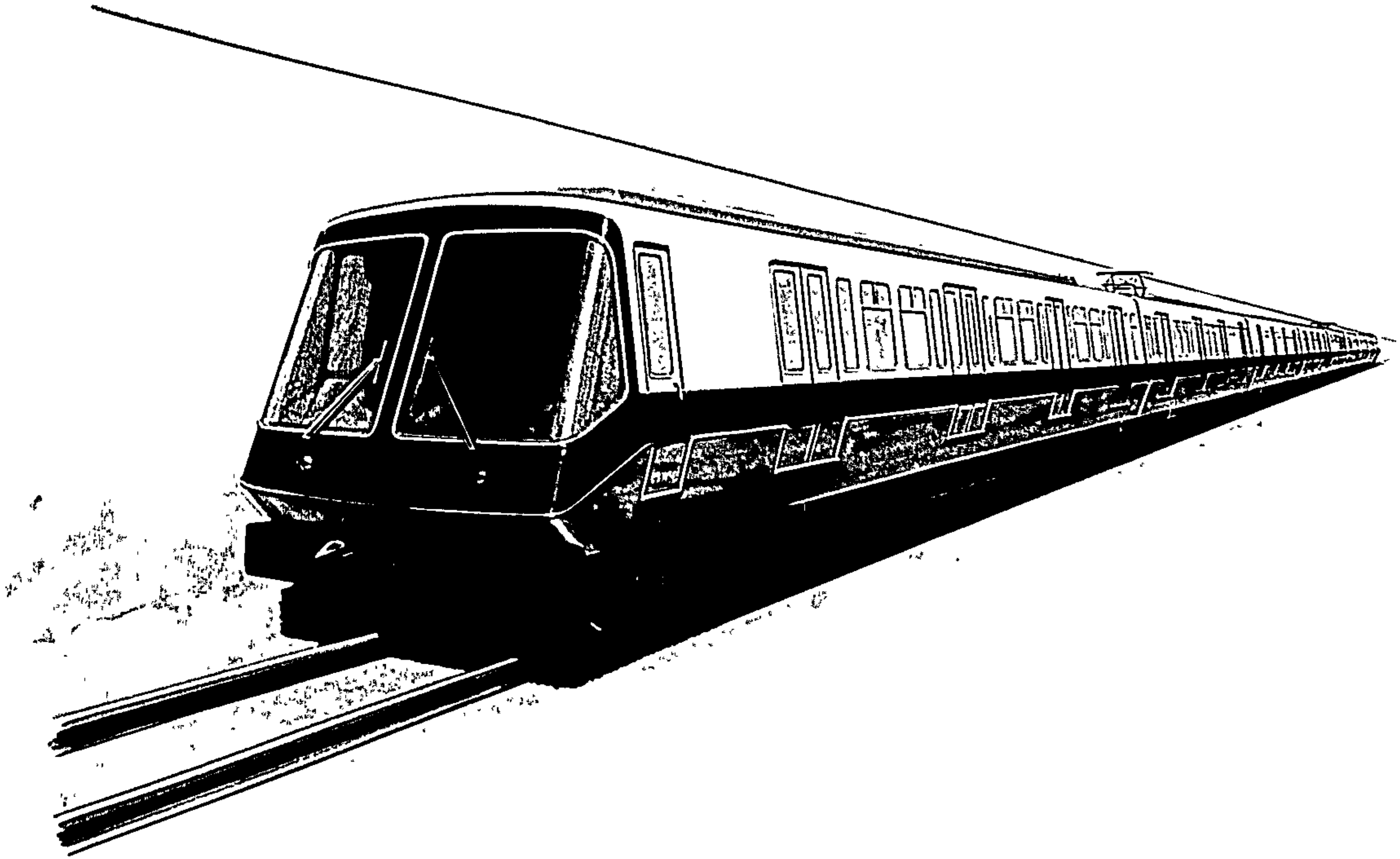
The Central Dispatcher is normally stationed at the Control Center and works for such services as the preservation and supervision of the functioning of the whole system, the arrangement for restoration from abnormalities, and the controlling of works such as recovery from accident, maintenance work, improvement work, etc., which may influence the normal condition of the system. For these purposes, it is necessary to keep constant and close contact with traffic control dispatcher and electric power control dispatcher.

The Central Dispatcher must make every effort particularly in the promotion of his engineering knowledge and ability, the understanding of the actual state of equipment, the well-arranged keeping of drawings and data, etc.

8-4-2 Field Organizations (Control of Individual Equipment)

Field organization should be adequate for inspection, recovery from failures, small-scale reconstruction works, etc. The number of personnel and the base, of such organization, are to be determined by the management system and failure restoration time.

As the facilities are constructed in a manner to be "maintenance-free", it is desirable to neglect daily inspections for most of the equipment and to combine (1) the material life-cycle control system, in which regular replacement of components is conducted as in case of relays, switches, transformers, rail insulators, etc., and (2) marginal value-control system, in which repair is conducted in conformity with the alarm represented where the prescribed value is out of the limits as in case of equipment provided with electronic circuits. The respective inspection system must be reviewed individually on some of the equipment which will need lubrication (e.g. turnout switches), water refilling (e. g. batteries), visual inspection (e. g. rail bonds) and comprehensive inspection (e. g. relay interlocking equipment).



Multiple-Unit Electric Train set of Suburban Railways in Mexico City

9. Vehicles

Since the Suburban Railways planned in Mexico has for its object the easing of traffic in the Metropolitan area, the vehicles as direct means of transportation must be such that has the performance, characteristics and structures suitable to mass transportation to meet its purpose. Among various railway facilities, the vehicles come into direct contact with the passengers, so must have duly attractive features. They are required to have smooth accelerations and decelerations, small amount of vibrations and noises, and good riding quality with bright and agreeable interior arrangement. They shall have smart appearance with coloration well looked with pretty landscape of Mexico City.

From the viewpoint of railway operation, on the other hand, simple operation and handling, easy maintenance and good economy are required, to say nothing of high reliability.

We have reviewed these many requirements and have worked out a plan for the fundamental performance characteristics and structure of the vehicles, based on our accumulated experience and achievements.

Below is given the description in this respect.

9-1 Required Performance Characteristics and Multiple Unit Cars Set

9-1-1 Acceleration and Deceleration, and Motored Car-Trailer Ratio

It is needed to find a ratio of motored car and trailer car, as one of the most fundamental element of a multiple unit cars set, which has a close relation with acceleration and deceleration required as train performance characteristics.

The tractive effort of a vehicle is obtained by adhesion between rails and driving wheels of a motored car, which adhesion is governed by the adhesion coefficient which is generally expressed in the formula below. To permit the stable running of vehicles without slip or skid, the tractive effort of vehicle has to be selected in a manner that it may be less than the value determined by the adhesion coefficient.

$$\mu = \frac{F}{10\ W} \quad (\%)$$

μ : Adhesion coefficient between rail and wheel

F : Tractive effort of motored car (Kg)

W : Weight of motored car (t)

Now, the relation among the multiple unit cars set, vehicleweight and acceleration is expressed by the following formula:

$$\alpha = \frac{F - r\,(a\,W_M + b\,W_T)}{108\,(a\,W_M + b\,W_T)}$$

and

$$\mu = \frac{F}{10 \cdot a \cdot W_M}$$

Where,

α	:	Acceleration	(m/s^2)
F	:	Tractive effort of motor car	(Kg)
a	:	Number of motor cars	
W_M	:	Weight of motor car	(t)
b	:	Number of trailers	
W_T	:	Weight of trailer	(t)
r	:	Running resistance	(Kg/t)
μ	:	Adhesion coefficient	(%)

From the above two formulae, we have

$$\mu = \frac{1}{10}\,(108 \cdot \alpha + r)\,(1 + \frac{b}{a} \times \frac{W_T}{W_M})$$

From this formula we have, with the acceleration taken as parameter, the relation between the required adhesion coefficient and the ratio of number of trailers to that of motored cars, as shown in Figure III-9-1. Here, it is supposed that the weight of motored car is 67t (tare45t + passengers22t), and that of trailer 57t (tare35t + passengers22t).

In this graph the abscissa 0 means no trailer included, that is, multiple unit cars set formed by motored cars alone. Abscissa 0.5 represents that the number of trailers is half of that of motored cars, and abscissa 1 indicates at that motored cars and trailers are same in number.

The original Mexican plan demands the acceleration of 1.0 m/s^2 as one of the basic elements of vehicle performance. As seen in Figure III-9-1, the multiple unit cars set needed to get this acceleration will greatly differ, depending upon what amount of adhesion coefficient can be expected.
If 30% can be expected as adhesion coefficient, one motored car can haul two trailers, leading to high economy. If μ is in the order of 11%, the multiple unit cars set composed wholly of motor cars is needed as the Figure shows.

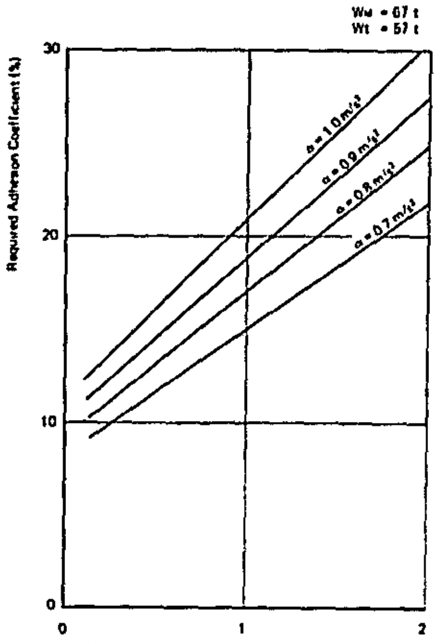


Fig. III-9-1 Train Composition and Adhesion Coeffication

It is therefore an important factor what amount of adhesion coefficient should be chosen. This coefficient, however, is difficult to get theoretically. It varies with weather or rail tread conditions and is also influenced by the vehicle control system.

In Japan this problem has been studied for a long time, and this long experience has given us to a conclusion that it is most rational to choose the value of 15 to 16% or less as adhesion coefficient for electric trains. This signifies that such multiple unit cars set is desirable as will have the motored car-trailer ratio of 2 : 1.

It may be added here as to the deceleration that because the brake force is applied to trailers as well as motored cars and because the running resistance acts as a part of brake force, the expected adhesion coefficient may be smaller than in case of acceleration, if the required deceleration is supposed to be 1.0 m/s^2.

9-1-2 Method of Composing Multiple Unit Cars Set

(1) Composing of Multiple-unit Cars Set Unit

It was made clear through the review in Section 9-1-1 that desirable train formation is the multiple-unit cars set unit with motored car-trailer ratio of 2 : 1. If these three cars are made to form a unit expressed in the form of 2M1T (M for motored car, T for trailer), then the following two plans can be considered as method for composing a unit:

1) MTM' System

This method will have a trailer at the middle of the unit, and motor cars on both ends.

The intermediate trailer is to be equipped with electric power equipments such as pantograph, transformer, rectifier etc. for power supply to the motor cars, with these three cars connected together electrically and coupled together quite permanently to form a fixed unit. The characteristic feature of this method lies in easy balancing of axle loads of motored car and trailer. Yet the following MM'T system is superior in many points.

2) MM'T System

The electric equipments are all mounted on two motored cars M and M', which are permanently coupled together electrically to form a unit, with the trailer T equipped only with mechanical brake system, serving as a mere trailer.

Although this system may produce a difference in tare weight between cars M & M' and car T as compared with the system described in 1) above, this system has extensive merit such as better adhesion characteristics hard to give rise to slip or skid, simpler main circuit wire connections between vehicles, leading to easier handling for coupling and uncoupling of vehicles, and free choise of coupled position of car T, leading to better operational convenience of vehicles and so on.

We recommend therefore the system MM'T as a basic multiple unit cars set unit.

(2) Composing of Multiple Unit Cars Set

The number of vehicles in a multiple unit cars set will be six (6) at the minimum to twelve (12) at the maximum.

Care to be taken in composing a train formation is that the number of types of vehicles should be limited to the minimum. For six (6) vehicles, the following four (4) plans can be considered :

a) Tc M M' M M' Tc

b) Tc M M' T M Mc'

c) Mc M' T M M' Tc

d) Mc M' T T M Mc'

The suffic "c" suggests a controlling vehicle with driver's cab.

The number of types of vehicles is 3 for Plan a), 5 for b), c) and d), which suggests the Plan a) is the most advantageous. A leading car has to be a controlling vehicle with driver's cab, which will have many accessory components in case of automatic train operation and should preferably be not a motor car. Also in this meaning, the Plan a) is desirable.

From these considerations, the train compositions shall be as follows:

For 6 vehicles : Tc M M' M M' Tc

For 9 vehicles : Tc M M' T M M' M M' Tc

For 12 vehicles: Tc M M' T M M' T M M' M M' Tc

Note : The position of T may be on either side of MM' considered as a unit.

9-1-3 Required Output and Performance Characteristics of Vehicles

(1) Conditions for Required Output Calculation

Review and study was made by a modeling method, based on the original Mexican plan and under the following conditions:

1) Average interstation distance 2.6 km
2) Acceleration and deceleration 1.0 m/s^2
3) Average interstation speed 60 km/h
4) Max. speed 110 km/h
5) Weight of vehicle Motor car : Tare 45t + Passengers 22t
   Trailer : Tare 35t + Passengers 22t
6) Train formation Tc M M' M M' Tc
7) Max. gradient 3 %

(2) Calculation of Required Output

As a result of calculation by an electronic computer the operating time and RMS current(*) of a main motor, changing the vehicle output and rating speed vary in various ways, it has been concluded that it will be most suitable to choose 180 kW for required output per main motor and 60 km/h for rated speed.

(*) RMS current

When electric cars run in a certain section, the main motor current varies much with time. The electric current is large at the time of acceleration, decreases gradually with increase in speed of the car, and is cut off for coasting after running of a given distance. If electric brake is used, a large current will flow at the time of brake application. The temperature of main motor is raised in a complicated variation by the current thus changing much with time, which is replaced by an equivalent constant current (supposed to produce the same heating effect), referred to as RMS (Root Mean Square) current expressed by the formula:

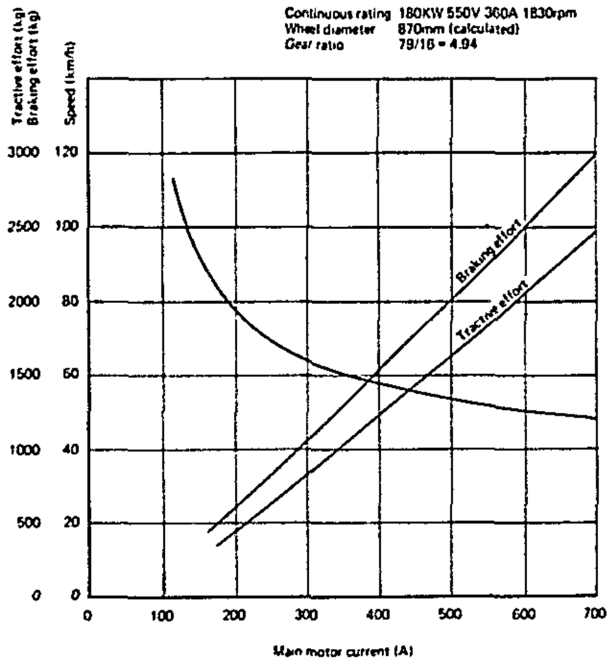


Fig. III-9-2 Main Motor Performance Characteristics Curves

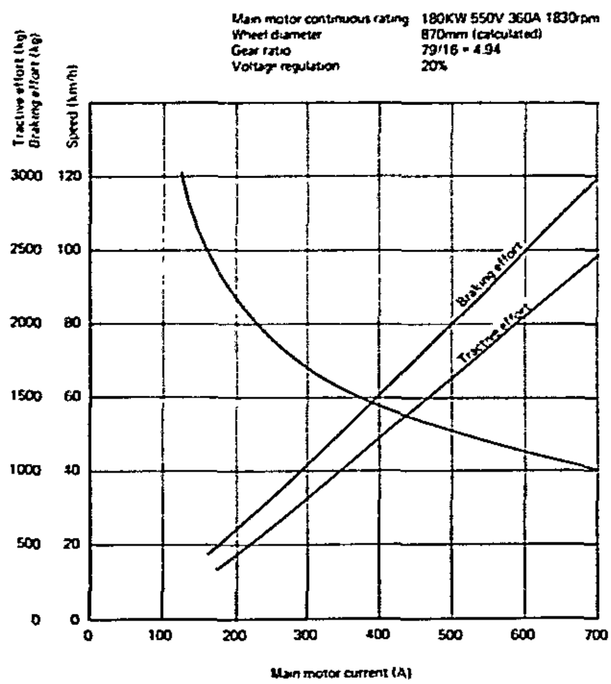


Fig. III-9-3 Electric Car Performance Characteristics Curves

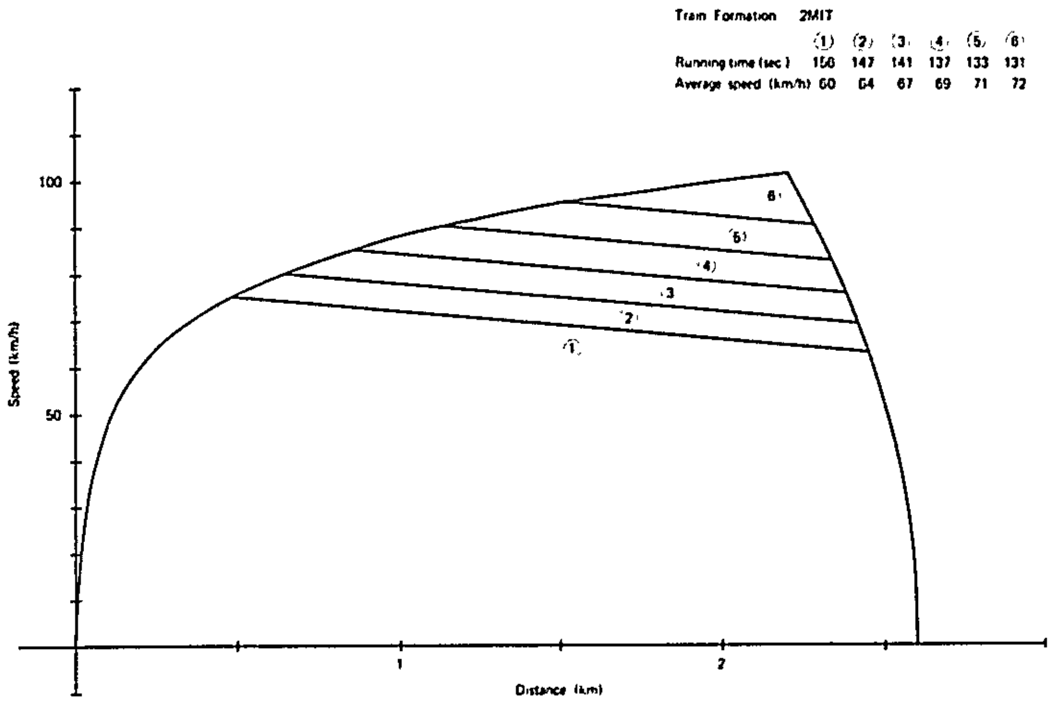


Fig. III-9-4 Train Running Curves

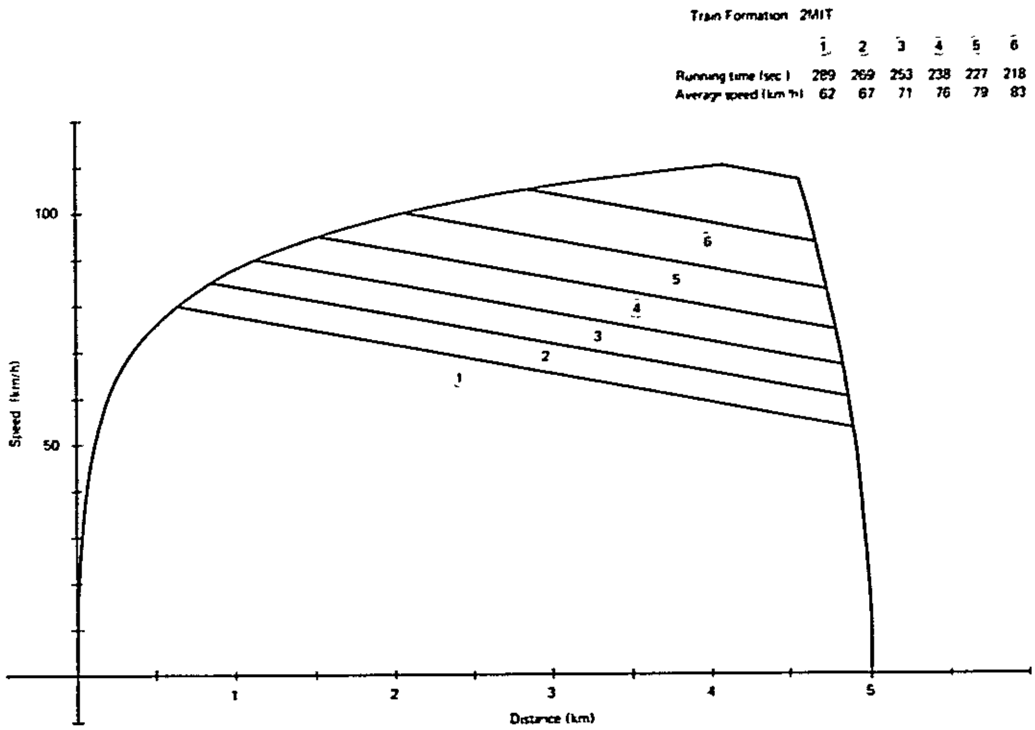


Fig. III-9-5 Train Running Curves

$$I_{R.M.S.} = \sqrt{\frac{\int i^2 dt}{T}}$$

where i is the momentary current value of main motor, and T is the total operating time.

The planned main motor characteristics are given in Figure III-9-2, the electric car characteristics in Figure III-9-3, and the operation running curve in Figure III-9-4.

From Figure III-9-4, we have the operating time of 147.3 sec., and average speed of 63.5 km/h, in case of interstation distance of 2.6 km, if the current is switched off and coasted at the speed of 80 km/h.

In a case that distance of interstation is long as 5 km or so, the running performance curve will be as shown in Figure III-9-5. The train speed can reach to the maximum speed of 110 km/h.

It may be added that as a result of calculation byan electronic computer also on the practical line shown in the attached Figure III-5-1, the appropriateness as the required output was confirmed.

There is a possibility considerable that one of the motor cars unit (MM') of the train formation may fail, and leading to stoppage on a 3 % up gradient in the worst case. It is desirable in the Suburban Railways with high traffic density that even in such case the train can run without causing disturbance in train diagram. The review result shows that the running will be possible, though lowered in performance.

9-2 Fundamental Vehicle Structures

9-2-1 Vehicle Gauge

The vehicles are planned and designed as AC electric cars, and the attached Figure III-9-1 represents the clearance gauge of the vehicle prepared based on the general arrangements of the vehicle of the original Mexican plan. The lower part of the vehicle gauge for trucks is pursuant to the AAR standard, with consideration to the future extension of the Suburban Railways to be connected to the existing National Railroad tracks. The limitation for motor the electric car is drawn included the hight of folded pantograph above the roof hight of the AAR standard.

9-2-2 Vehicle Construction

(1) Fundamental Vehicle Layout

There are four types of vehicles:

Tc : Trailer with driver's cab

M : Intermediate motored car

M' : Intermediate motored car with pantograph

T : Intermediate trailer

There are four types of vehicles, but as a fundamental concept for the layout of the car bodies, the fundamentals of the car body construction shall be the same with one another and be standardized in design and manufacture as much as possible. For such standardization purposes, the intermediate motored car type M shall be taken as a basis, with the car M' being considered to have a pantograph added to the car body construction of vehicle M, and the intermediate trailer T being considered to have the same car body construction as M. The trailer with driver's cab Tc shall be considered in a manner to remove seats at end of car M and replace the area with a driver's cab. By so doing, all types of vehicles shall have the doors at the same positions - that is enable the passengers at the platform access to the train.

The vehicles shall be large-sized car body length of 24,500 mm and distance between coupling faces of 25,000 mm, suitable to mass transportation, and shall have four access openings of 1,600 mm each in width disposed on each side at the same pitch so as to shorten the time needed for getting on and off of passengers.

The layout drawings of the vehicles are illustrated in the attached Figure III-9-2 (Tc, M, T) and in the attached Figure III-9-3 (M').

As motive power is dispersed over the train of multiple unit electric cars, it is considered that the car body can withstand the longitudinal compression force of 100 metric tons.

(2) Car Body Materials

Steel and aluminium alloy can be considered as car body materials. Steel car bodies have been long experienced in manufacturing and using and they are so popular for railway vehicles. However as recently vehicles made of aluminium alloy have been manufactured in a great number, and they have many advantages.

Aluminium alloy has two characteristic features: light weight and high corrosion resistance, accompanying many advantages.

Specific gravity of aluminium alloy is about one third of that of steel, and aluminium alloy has high strength in spite of its light weight. When used for the construction of car bodies, aluminium alloy is expected to bring about approx. 4 tons weight saving as compared with steel car body structure weight of approx. 14.5 tons. The light weight construction brings about electric power cost saving, reduction in track load, and decrease in brake shoe abrasion.

Owing to high corrosion resistance and less corrosion than steel, the aluminium outside sheathing will do only with simplified painting, which is advantageous with respect to maintenance. Yet, from esthetic point of view, they may be given painting. Due consideration need be given.

Furthermore, the aluminium alloy, unlike steel materials, are available freely in the form of extruded shapes of various cross sections, thus permitting a reduction of welding process in the construction of car structural frames and at the same time enabling us to produce rational cross sections in view of their strength.

The disadvantage lies in a larger difficulty of aluminium welding technique than that of steel and higher cost. (Increase in cost is estimated to be about 5% per vehicle, compared with steel construction.)

(3) *Seat Arrangement*

The seat arrangement shall be the same for vehicles types M, M' and T, with cross seats for aged or infant passengers at both ends of vehicle and longitudinal seats in the intermediate, to suit the mass transportation of the Suburban Railways.

The vehicle Tc has a driver's cab at one end of the vehicle in place of cross seats removed, having the same construction with other types of cars except this cab.

The passenger capacity by types of vehicles are as follows:

	Passenger capacity	Seating capacity
Tc : Controlling car with cab	330	62
M : Motored car	357	70
M' : Motored car (with pantograph)	357	70
T : Trailer	357	70

(4) Accessories

1) Passenger access doors

There can be considered the outside hanging type door and the drawn into door pocket type door.

The outside hanging type has some advantages in esthetic aspects (outside door surface flush with the car body outside sheathing) and in car body structures (its simplification), but has a higher danger of hurting passengers at the time of opening and closing and a rather complicated door closing mechanism. Then, the drawn into door pocket type door is recommended.

2) Gangway doors at vehicle end

There can be considered the inward opening, outward opening and sliding types of doors, among which the sliding type is recommended in consideration of safety and handling in case of full passengers.

These doors will not be used at usual time, but be used at emergency for escaping out of the vehicles. Therefore no bellow is needed at coupling areas between vehicles. Yet the folding-up type apron will be provided.

3) Windows

Windows will be of two-leaf type, with the lower half fixed and upper half rotating inward. For giving comfort to passengers and for esthetic purposes, the windows shall be constructed in large size.

4) Ventilation

Electric propeller fans shall be provided on the ceiling for room ventilation. Air conditioning (heating and cooling) is not needed for environmental conditions in Mexico City.

5) Ceiling lamps

Fluorescent lamps are to be used for bright and comfortable room conditions. Incandescent lamps shall also be provided as emergency lighting by battery power source in case of catenary power failure.

6) Interior panels, etc.

Inside of car body shall be lined with aluminium sheet laminated with melamine plastic resin for bright and maintenance-free interior finish. Nonflammable materials shall be used with due consideration given to the countermeasures against fires. Insulating materials shall be applied to the outside sheathing in order to reduce the heat and sound transmission.

Hand rails shall be properly arranged for standing passengers to prevent them from staggering and parcel racks shall be also provided.

The seats shall be of such construction as will be comfortable to sit on, and of cantilever structure in order to make easily cleaning the room.

9-2-3 Principal Equipments and their Disposition

(1) Vacuum Circuit Breaker

This is a circuit breaker which is connected to the trolley side on the primary winding of the main transformer and serves to open the circuit for protecting the vehicles in case of any abnormality such as grounding or short circuit of the main electric circuit. It has contact tip in a vacuum interrupter to improve the breaking performance and reduce its own weight.

(2) Main Transformer

This serves to lower the voltage of AC 25 kV from the pantograph through the vacuum circuit breaker and supply it after rectifying to the main motors and directly to auxiliary circuits. The secondary winding will be divided into four sections each of which will be connected to a rectifier unit and serve as power source for the main motors.

The tertiary winding are to serve as power source for auxiliary rotating machines and other interior equipment. Main transformer is of oil-immersed forced ventilation type. It shall be of "form fit" type, most suitable to reduce its weight.

(3) Main Rectifier

This converts the AC secondary voltage of the main transformer into DC voltage and is composed of four mixed bridge units formed by thyristors and diodes arms. Each unit is connected to the split secondary winding of the main transformer. These units are connected together in series. DC output voltage will be continuously controlled by phase control of thyristor.

(4) AC Filter

AC filter is provided to absorb abnormal voltage of the secondary side of the main transformer and to protect rectifying elements. This AC filter is composed of capacitor and anti-resonance resistor and connected to each secondary winding circuit of main transformer.

(5) Smoothing Reactor

Direct current obtained through rectifier has much ripple current because of single-phase circuit. The ripple current will raise commutation trouble of main motor. Smoothing reactor is provided to smooth the current to improve the commutation.

(6) Main Motor

This is a direct current series motor type, but actually pulsating current flows. Smaller pulsation factor is desirable for commutation of main motor, but the dimension and weight of smoothing reactor consequently become larger and at the same time the inductive disturbance to signal and telecommunication system will be increase due to deformation of the trolly current. Therefore, main motors capable of resisting a large pulsating current is desirable. Japan has a good experience also in the use of pulsating current motors with 50 to 60 % pulsating current radio through a long-time study and good achievements for a lighter-weight construction of main motor and for improvement of inductive disturbance.

The main motor is mounted on the truck and supported in such away to isolate the vibrations from track.

(7) Main Resistor

This is for dynamic brake and is made of special steel of small temperature coefficient and of air-cooled type.

(8) Main Controller

This is provided to control remotely the dynamic braking current in accordance with the handle position of the driver, and is used as powering and braking changeover switches.

(9) Circuit Breaker

This is to open the main motor circuit. In powering, the circuit breaker opens generally after the current has been attenuated by thyrister gate off. At the time of accident, however, this circuit breaker open the circuit in connection with over current relay. At the time of dynamic brake application, this circuit breaker breaks the circuit also by detection of over current.

(10) Motor-generator

This is of 2-phase ac generator type driven by a single-phase induction motor supplied from tertiary winding of main transformer as power source. It supplies ac power source to control and lighting circuits with small voltage variation irrespective of large fluctuation of catenary voltage.

The direct current used for control is obtained by rectifying the alternate current generated by this motor-generator.

(11) Motor driven air compressor

This is provided to supply compressed air for air brake, opening and closing of doors, circuit breaker, air spring, whistles, etc.

(12) Batteries

Alkaline batteries will be provided for control power source and emergency service-power source.

(13) Brake Unit

This is to control the air brake force of each vehicle in accordance with command dispatched by a motor man, and is constructed by integrating various electromagnetic valves, cut-out cocks etc., into a unit, in order to get rationalize the manufacture, facilitate maintenance, and improve performance.

(14) Air Reservoirs

The air reservoir serves to store the air source of air compressor. This also becomes various air sources needed for brake control.

(15) Junction Boxes

Provided at the ends of vehicle will be the junction box of wires connecting between vehicles, and plugs, plug sockets etc., which facilitate the handling.

The state of installation and fitting of these principal equipment of vehicles are illustrated in the attached Figure III-9-4 for vehicle M and in attached Figure III-9-5 for vehicle M'.

9-2-4 Bogie Trucks

Bogie trucks serve to let vehicles run in safety and give direct influence to riding quality. Therefore, review was conducted on a basis of systems and structures well proven in use and having good performance results.

(1) Bogie Truck Structures

Bogie truck frames are of welded steel plate construction composed of steel H shapes intended to be light-weight in a simplified way.

A car body is supported on truck frames by air sprimgs through a body bolster, with coil springs placed between axles and bogie truck frames.

The rotation of the car body and a bogie truck with each other is supported between the body bolster and the bogie truck frames, and the longitudinal and transverse displacements are supported by the rigidity of air springs. The traction and braking force is transmitted to the car body through bolster anchors connected with bogie truck bolster and car body.

The driving truck and the trailing truck are similar in construction except the existence of main motor and driving system and the difference in air brake system. The layout of driving truck is shown in the attached Figure III-9-6, and the layout of trailing truck in the attached Figure III-9-7.

(2) Wheels and Axle

Wheels are rolled monoblocked steel wheels of 36" in diameter when new, and are press-fitted to an axle.

Driving axle has a gear seat, and trailing axle has a brake disc seats.

(3) Axle Boxes

There are many types of axle box guiding system. From viewpoint of better riding quality with softer springs and easier maintenance with dust-proof construction and simpler assembled and disassembled works, we adopt the cylindrical guiding system.

Cylindrical roller bearings is the most suited, judging from resistance to loads and a longer service life. Especially in these bearings, we choose cylindrical roller bearings with collar, which are simple in construction and advantageous in maintenance features because such component parts for absorbing the shocks of transverse motions are not required.

(4) Driving System

To protect a main motor from being damaged due to impact from the track and wheels, it is essential to mount it above springs (at sprung areas). This will guarantee the miniaturization and weight reduction of main motor and good erctifying characteristics and lead to the prolongation of service life. There can be planned various types of sprung mounting, but we adopt flexible gear joint system, from structural and maintenance points of view, since the track gauge of 1,435 mm gives sufficient space for the purpose.

This is a combination of two sets of inner and outer gears. This can give flexibility between main motor shaft and pinion shaft, and flexible transmission can freely obtained in spite of eccentricity or inclination of both shafts.

The pinion and gear are mounted in gear box and supported by bogie truck frame and axle.

(5) Air Brake System

The trailing trucks will depend wholly on air brake system. The system of pushing brake shoes on wheel treads will deform the tread contours and worsen the running performance, and shorten the service life of wheels. The system we have chosen, therefore, is such that the brake linings clasp on the faces of a brake dids fixed on the central part of an axle. The disc will have fan-shaped cooling fins to increase cooling effects against heating.

The driving truck, which is provided with main motors, has no such space for mounting brake disc as a trailing truck has. The wheel tread brake is not desirable similarly, and such system is to be adopted as will utilize the disc faces of wheels.

The disc faces, so constructed as to be divided into two halves, can be given maintenance independently without influencing the wheels, even where worn disc faces will be required to replacement.

Brake linings to be adopted shall be resin type shoes well-proven in long-time use in Japan.

This performance is unchangeable in coefficient of friction and secure almost constant brake forces, and further have the advantages of very small abrasion and care-free maintenance.

(6) Air Springs

Air springs serve to isolate the high-frequency vibrations transmitted from the truck for ride quality improvement, keep the car body height at a constant level dependently of the amount of passenger load and balance the vehicle in transverse direction.

The air spring system is composed of special diaphragm having appropriate rigidity in vertical and transverse directions, and the vertical damping is secured by a choke provided between diaphragm and auxiliary air chamber.

9-3 Vehicle Control System

9-3-1 Main Circuit Arrangement

These electric cars are composed in such a way that two vehicles form one unit electrically, as mentioned in Section 9.1.

The electric source is 25 kV, 60 Hz AC, and pulsating current series motors are used as main motors. Such AC voltage is lowered by main transformer, converted into DC through rectifier and supplies to eight (8) main motors.

The main circuit arrangement is shown in the attached Figure III-9-8.

(1) Powering Circuit

1) Main Transformer and Rectifier

The main transformer serves to lower the high voltage of the primary side. In order to reduce inductive disturbance to communication lines, the secondary side will be divided into four sections. Each divided winding will be connected to a mixed bridge unit consisting of thyrister and diode bridge arms.

Theoretically, the more the number of such division in the secondary side increases, the more great reduces the inductive disturbance. But practically, the main transformer and the rectifier will increase in weight and complicated, in cost as well. In this meaning division into four (4) or so will be most suitable.

Dc output voltage of the rectifier will be controlled as mentioned below. As the rectifier units are cascade-connected four in series, at first the phase angle of the thyristor of No. 1 unit is controlled and output voltage of No. 1 unit increases continuously up to the maximum. During this operation the upper mixed bridges (No. 2 to No. 4) function as fly-wheeling diode.

At the second stage the phase angle of the No. 2 unit is controlled just in the same moad e as No. 1 unit and the output voltage of No. 2 unit is integrated to the voltage of No. 1 unit.

In the same pattern the output voltage of No. 3 and No. 4 unit will be integrated.

By thyristor control, the main motor voltage will increase continuously and smoothly. Thus the excellent characteristics can be obtained with respect to vehicle performance, riding quality and maintenance free since the thyristor application does not necessitate mechanical contact.

2) Connection of Motors

Eight motors of one motor car unit (MM') will be controlled simultaneously. Four types of main motor connection were compared : 8S (8 motors in series), 4S-2P (4 motors in series and 2 motors in parallel), 2S-4P (2 motors in series and 4 motors in parallel) and 8P (8 motors in parallel). Now 8S necessitates too high secondary voltage and 8P necessitates too large secondary current, 2S-4P has an advantage that power reduction in failure of one motor circuit is small because it has four parallel circuits. But the balance of weight distribution among the vehicles is hard to obtain, compared with 4S-2P. In addition the total weight of electrical equipment will be larger. Then it is recommended to apply 4S-2P connection because this system permits the train to operate with one motor circuit opening the failed motor circuit and weight can be well balanced between vehicles M and M'.

(2) Electric Brake Circuits

Electric brakes are classified into regenerative brake and dynamic brake.

The regenerative brake is a desirable system from a standpoint of regeneration of electric braking power, but has defects such as complicated mechanism of control for variation in catenary voltage, functional inability of regenerative brake at the time of pass through catenary-jointing sections, narrow speed range at which the regeneration brake is available large inductive disturbance and operational inability of regenerative brake at supply power breakdown.

Dynamic brake, on the other hand, has a constant electric braking effort always independent from the catenary conditions in wide speed range. This leads us to adopt the dynamic brake system.

In dynamic braking the main motors will be cutoff from the secondary circuit of the main transformer, and at the same time with the field polarity against in powering reversed to make the main motors act as generators, and with load resistances connected. The main motors shall be connected, four in series, to form two circuits. The control of dynamic brake forces will be made by increasing or decreasing the load resistance by the control device.

9-3-2 Brake Control

(1) Functions Necessary for Brake Control

Very high-grade functions are required for the brake control of vehicles operated at high speeds and with large accelerations and deceleration of such high traffic-density track sections as suburban railways.

The most important thing is, at first, the high reliability of the system and the existence of "fail-safe" system in which the system functions in safety side in any failure effort and then, easy operation and handling, that is, the brake can be controlled in accordance with the will of a train driver. For that purpose the reduction so-called "dead time" - time needed for actual brake application after the braking command will be needed. And the improvement of the accuracy of the commands itself of braking effort control, and the response characteristics must be completed.

Further, when the electric brake is adopted, a smooth transition between electric and air brakes from one to the other is required. Extremely efficient application of electric brake is desirable for reducing the abrasion of brake shoes.

For that purpose, such brake control system is reasonable:

(Command brake force) - (Electric brake system)
= (Supplementary air brake system)

(2) Brake Control System

Service brake system is such that will directly controls the electric and air brakes by means of electric commands, by connecting, with train wires (electric wires running the full train length), the brake control valve of a driver's cab and underfloor brake equipments of each vehicle of a train, and thus improve the response characteristics of brake and shorten the dead time of the brake force. This system

system permits the synchronized brake application to each vehicle even of a long train formation not producing unbalance of the braking forces among the vehicles.

In order that a constant deceleration may be secured by a driver's handle operation, irrespective of small or great number of passengers, each vehicle is provided with a weight responsive brake device - a mechanism which permits the application of a large braking force in proportion to a large passenger load.

In emergency brake system exist the controlling wires (running over the train) always kept charged with electric voltage and the emergency brake may be applied if such wire gets "off". Under such state, the brake can be operated from any position in a vehicle, and the ensured emergency brake application can be secured in any of the cases of electric source, such as uncoupling of vehicles in a train, loss or air source and etc.

Besides two brake systems, service and emergency, there shall be provided a security brake with a different compressed air source, to improve the reliability by thus forming a multiple system.

In addition, braking effort checking circuit shall be provided with to improve the safety of system. This means that shortage or excess of braking effort should be detected and corrected. Therefor the difference between the command value and the actual value shall be detected and necessary correction shall be made.

9-3-3 Automatic Train Operation System and Functions

There are two ways of vehicle operations; manual and automatic. Which to choose gives a great difference in various equipment to be used on the vehicles. Manual operation of vehicles is such that a motor man directs coasting or braking by handling the operating handle in his will, and the automatic operation is such that vehicles are operated automatically up to the next station by pushing the start button and that the train crew works only for supervising the cab equipment. In either case, however, train operation will be back-uped by ATC to avoid such accidents as a rear-end collision.

Since manual operation is a conventional type, here is given description on the functions of automatic operation.

(1) Outline of the System

1) The safety of trains is to be secured by ATC.

2) The train crew performs the "door closing" operation, and after the doors are closed, the train automatically starts.

3) Constant - speed running is available with proper speed allowance to ATC permissible operating speeds.

4) The train stops automatically at prescribed position at the station platform.

5) After the train stops, the doors are opened by means of "door opening" operation by the crew.

6) The train has arrived earlier than the prescribed time, the adjustment is to be made by prolonging the start time.

7) The programming shall be such that a higher running speed will be automatically selected in case of later than the prescribed time, to recover the schedule time.

With these functions incorporated, the operations made by crew at normal time are merely to handle opening and closing the doors.

(2) Functions Needed for Vehicles

Besides the functions necessary for manual operation, the following functions are to be added:

1) Constant-speed train operating function

This is the controlling function to make the train run in constant target speed. Control of the vehicle speed will be executed by detecting the difference between the target speed and the actual speed.

2) Function of setting the target speed

This is the function which permits the automatic selection of the target operating speed, based on the judgement of whether the train is on or behind the schedule through comparison with the prescribed time.

3) Function of stopping at the prescribed positions

This is the controlling function permitting the automatic stopping of trains at prescribed positions of the station platforms. The prescribed distance-speed pattern generator will be provided along which the braking forces are to be controlled automatically.

In addition, a ground coil is provided at a certain distance in advance of the prescribed stopping position of a station platform, so as to generate on-cab patterns.

4) Supervising and other functions

Such functions are necessary to display the working conditions of equipment, and to detect and display the failures.

These equipment shall be installed integrally in a motor man's cab.

The Investigation Committee proposes the vehicles with automatic train operation as described herein as Plan-A, and the vehicles for manual operation as Plan-B. The Plan-A will have an increase in cost by about 6 % in average per vehicle, compared with the Plan-B.

9-3-4 Auxiliary Circuits

Vehicles need electric power sources for many auxiliary rotating machines, lighting and control circuits. Those electric power sources are classified roughly into AC and DC sources, in addition each being divided further into those which wide voltage fluctuation will be permitted or no.

(1) AC Power Source

AC power source supplies oil pump of main transformer and for ventilating fans and air compressors for air cooling of main rectifier and main resistor. These power are directly supplied from the tertiary winding of the main transformer, and single-phase AC induction motors are to be used for such equipment.

(2) AC and DC Power Sources

The lighting power source for fluorescent lamps, if supplied directly from the tertiary winding of main transformer, will have too much voltage fluctuation and cause the fluorescent lamps flicker when the train passes through a catenary junction section. Some measures have to be taken to cope with this situation. There shall be provided, for this purpose, a motor-generator supplied from the tertiary winding, of which the (AC) generator is made to function as voltage regulator in such a manner that the motor-generator may have a small output voltage fluctuation irrespective of variation in catenary voltage and may cope with instantaneous power breakdown by its inertia as a rotating ma chine.

DC power sources for various controls are obtained by rectifying the AC output of motor-generator. In addition, batteries are installed as emergency power sources in case of catenary power failure and floating-charged at normal time by the output of motor-generator to prevent exhaustion.

9-4 Principal Particulars of Vehicles

To sum up, the principal particulars of vehicles recommended by the Investigation Committee are as follows:

9-4-1 Electric Power System

Single-phase AC 60Hz, 25kV

9-4-2 Types of Vehicles

	Passenger capacity (persons)	Seating capacity (persons)	Tare weight (tonnes)
Controlling car with cab: Tc	330	62	Approx. 35
Motored car : M	357	70	Approx. 44
Motored car (w/pantograph): M'	357	70	Approx. 45
Trailer : T	357	70	Approx. 34

9-4-3 Multiple-unit Cars Set

For 6 vehicles	Tc M M' M M' Tc
For 9 vehicles	Tc M M' T M M' M M' Tc
For 12 vehicles	Tc M M' T M M' T M M' M M' Tc

9-4-4 Performance Characteristics of Vehicle

(1) Max. operating speed 110 km/h

(2) Acceleration 1.0 m/s^2

(3) Deceleration in service 1.0 m/s^2
in emergency 1.3 m/s^2

(4) Continuous ratings (per one unit MM')

1) Output 1,440 KW

2) Tractive effort 8,500 kg

3) Speed 60 km/h

9-4-5 Car Body Principal Dimensions

(1) Distance between coupling faces	25,000 mm
(2) Car body length	24,500 mm
(3) Car body width	3,300 mm
(4) Roof height	3,730 mm
(5) Floor height	1,280 mm
(6) Standard pantograph height	5,220 mm
(7) Folded height of pantograph	4,510 mm
(8) Distance between center plates of bogies	17,500 mm

9-4-6 Bogie Trucks

(1) Type	Cylindrical axle box	
(2) Suspension system	Air spring directly mounted to car body	
(3) Structure	Welded steel plate construction	
(4) Wheel diameter	at new	36" (914 mm)
	at wear limit	824 mm
(5) Wheelbase		2,300 mm
(6) Track gauge		1,435 mm
(7) Driving system	Flexible gear joint system	
(8) Gear ratio		79/16 = 4.94

9-4-7 Main Motor

(1) Type	Pulsating current series motor
(2) Continuous rated output	180 kW
(3) Continuous rated voltage	550 V
(4) Continuous rated current	360 A
(5) Continuous rated revolution	1,830 r.p.m.

9-4-8 Control System

(1) Powering	Thyristor control system
(2) Brake	Air brake system, combined with dynamic brake
(3) Safety system	A.T.C.
(4) Operating system	Manual or automatic train operation

9-4-9 Main Transformer

(1) Type	Oil-immersed forced ventilation type	
(2) Voltage	Primary	25 kV
	Secondary	4-division, 745V x 4
	Tertiary	220 V

9-4-10 Main Rectifier

(1) Type	Forced air cooling
(2) System	Combined thyristor-diode bridge

9-4-11 Auxiliary Rotary Machines

(1) Auxiliary machines		Single-phase induction motor type
(2) Motor-generator	Motor	Single-phase 60Hz, 220V
	Generator	2-phase 60Hz, 100V, 20kVA
(3) Motor-air compressor		Single-phase 60Hz, 220V
(4) Ventilators, fans, oil pump		Single-phase 60Hz, 220V

9-4-12 Car Body Construction

(1) Car body structure	Aluminium or steel
(2) Interior panells	Aluminium sheet laminated with melamine plastic resin
(3) Floor	Corrugated steel sheet, Lightweight flooring compound, Polyvinyl chloride flooring sheet
(4) Side windows	Fixed lower half, inward-opening upper half unit type, Fixed type door pocket window
(5) Side sliding doors	Automatic bi-parting sliding door, drawn into door pocket
(6) End doors	Sliding type
(7) Gangway	Folding up type apron
(8) Seats	Cantilever support, vinyl leather covering
(9) Hand rails	Stainless steel pipes
(10) Ventilation	Natural ventilation and forced ventilation by overhead electric propeller fan
(11) Ceiling lamps	Fluorescent lamps, and emergency use incandescent lamps

(12)	Thermal insulation	Glass fiber
(13)	Car body compression load	100 tonnes

9-4-13 Hand Brakes

Hand brake system shall be provided in a controlling vehicle with cab for parking the train.

10. Car Depot and Workshop

10-1. Car Inspection System

When the cars are continuing operation service, they will gradually suffer from abrasion, deterioration, corrosion, etc., and their performance and characteristics will becomes lessened. There are two types of methods for their restoration: corresponding maintenance and preventive maintenance. The cars of suburban railways, have very important mission transporting many passengers of precious human lives safely and securely. The preventive maintenance system should be adopted for achieving this mission, and it will afford chieper maintenance cost considering in long-term viewpoint. This system aims at the recovery of the original performance and functions by inspecting the state of cars after a prescribed period or running distance and by repairing and replacing the deteriorated parts.

If these inspections and repairs are suited to the purpose, the cars will be kept constantly in good conditions and be ready for safe and punctual transportation.

For these purposes, the types, details and cycles of inspection and repair are set to guarantee the required performance and functions of cars from one inspection to the next inspection with many years of experiences in Japan, taken into account. (Table III-10-1)

Speaking of the places where the inspections are to be conducted, the general inspection and main parts inspections are to be conducted at workshop, the monthly and daily inspections at car depots, and the extra inspections at workshop or car depots according to the degree of inspection, judging from the time required for inspection with relation to the car operation, and the degree of dismantling for inspections and the centralization of the facilities.

The inspection cycles should be shortened for the time being after the inauguration and then be gradually enlonged to the proper periods as indicated in footnote of Table III-10-1, in case of the inauguration of the railway line and introduction of new types of rolling stock, because the requirement of learning treatment and techniques, and for inspection and repair terms will attain to their aimed period and because the grasp of actual health-condition of cars requires considerablely long period through the accumulation of experience in the inspections and repairs.

Table III-10-1. Types, Details, Cycles and Site of Inspections

Types and Details of Inspections			Inspection Cycles		Site of Inspection
Types		Details	Inter-vals	Running Distance	
Periodical Inspection	General inspec-tion	Inspection conducted comprehensive-ly in detail by dismantling each com-ponent part at prescribed intervals depending on the state of use of the electric car.	4 years or less (3 years or less)	600,000km or less (500,000km or less)	Workshop
	Princi-pal Equip-ment	Inspection conducted at prescribed intervals depending on the state of operation of cars for the condition, pal equipments such as main motors, trucks, running gears, brake equip-ments, current collectors, auxiliary motors, relays, contactors, couplers, ATC devices, instruments etc., and by dismantling specified principal parts for details.	2 years or less (1.5 years to less)	300,000km or less (250,000km or less)	Workshop
	Month-ly inspec-tion	Inspection conducted at prescribed intervals depending on the state of operation of cars for the condition, actions and functions of pantographs, high tension circuits, main circuit system, rotary machines, door operating devices, brake equipment, trucks, running gears, ATC devices, instruments, etc. in as-installed state.	60 days or less (30 days or less)	30,000km or less (15,000km or less)	Car depot
	Daily inspec-tion	Inspection conducted from outside in conformity to the state of operation of cars for replenishment and re-placement of abrasive parts and for condition and action of pantograph, door operating devices, interior equipment, trucks, running gears, coupling devices, etc.	48 hours or less	3,000km or less	Car depot
Occasional	Extra inspec-tion	Inspection conducted whenever need arises because of trouble of rolling stock.	Occa-sional	-	Workshop, Car depot

Note: The inspection cycles in ( ) shall apply temporarily to the initial period immediately after the railway inauguration.

10-2. Car Depots

10-2-1. Location of Car Depot

It is necessary, for deciding the location of a car depot, to make a comprehensive review on the forms of transportation, the geographic conditions, car utilization and others. To be concrete, the location shall be planned on the following concepts:

(1) The location such as a place where a large difference in traffic volume, before and behind

(2) The location such as a place where enabled the high efficiency of car utilization

(3) The car depot shall be appropriate in scale to meet the assigned work

(4) Personnel and workers are available easily

(5) Land suitable for car depot can be obtained easily

(6) Construction cost is not expensive

The location of car depots will be determined through sufficient study on the relative position of the car depot to the station from which the car depot branches, taking the following points fully into consideration:

(1) It will be situated as near as possible to the station in order to reduce loss in utilization of drivers and cars with minimum deadhead operation

(2) The trains can enter and leave the car depot, directly to and from the station with minimum work

(3) Deadheading tracks shall be designed in such a manner that the level crossing can be changed into grade separation crossing with main line tracks in the future.

The abovementioned concept has made it clear that one car depot is sufficient for the service at the stage of inauguration in 1982. However the following three depots are planned for the reasons that, if the car depot is centralized in one location, the deadheading loss will increase as there are substantially four separate lines, and the number of cars will increase along with the extension of railway network and the increase of traffic volume:

For Line No. 1 : at Los Reyes

For Line No. 2 : at Ecatepec (where a workshop is also to be located.)

For Lines Nos. 2, 4&5 : at Xalostoc.

Layouts of car depots are shown in the attached Figures III-10-1, III-10-2, and III-2-3.

10-2-2. Standard Facilities in Car Depot

The track layout in the yard of car depot is restricted by the geographic conditions, but it should be arranged so that the entering to and leaving from the car depot, parking, making up of trains, washing and cleaning, inspection and repair. Each work in depot car be performed efficiently without mutual interferences;

(1) Track layout in the car depot

The track groups in the car depot are classified by types of operation into storage track group, servicing track group, and inspection and repairing track group. The essential points in planning of track layout are as follows:

1) Access track

The access track (entrance and exit track) is separated from main line track in principle and is arranged in such a manner as to enable the entrance and exit without being disturbed by other operations in the car depot.

2) Parking track

The parking track shall have the layout with direct communication to the access track, and each shall have parking capacity of one or two train sets. The parking tracks in a large car depot are preferably to be through to both directions.

(2) Facilities for inspection and repair

The car depot shall be provided, with daily inspection facilities, monthly inspection facilities, repairing facilities and wheel lathing (milling) facilities based on the car inspection system:

1) Daily inspection facilities

The daily inspection house shall be installed adjacent to the monthly inspection house, with inspection pit, catenary idsconnecting switch, a roof inspection stand, ATC testing device, etc. Each daily inspection track shall be designed to permit 4 to 8 inspection per day.

2) Monthly inspection facilities

Train sets differ in the number of cars, from 6 to 12, depending on lines. The cars shall be inspected in one train set, as a rule, because a train consists in one-set.

The principal facilities are inspection house, inspection pit, roof inspection stand, catenary disconnecting switch, ATC testing device, comprehensive testing system, air pressure pipes and electric power source facilities.

3) Repair facilities

Minor repairing works are to be performed in daily inspection house or monthly inspection house. But the repair of underfloor equipment which require the lift up of car body, and the replacement and repair of important equipment are to be performed in the repair house. The principal facilities are repair house, repair pit, equipment for inspection and repair work and lifting machines.

4) Wheel-tread milling machine

Flat caused on wheel-treads gives uncomfortable riding condition and are not desirable in the security of safety operation. Wheel-tread milling machine is necessitated desirable. When the cars are sent to the workshop for repair, operational efficiency of those cars is lessened, and the car depot will be provided with wheel-tread milling machine which permit the turning of wheel-tread in as-install state in a train set.

Table III-10-2 indicate the machinery to be equipped in the car depot.

Name of track or house	Name of machines
Servicing track	Car washing facility
Milling machine house	Wheel-tread milling machine
Inspection and repairing house	Filter cleaner Upright drilling machine Bench grinder Electric welding machine Vacuum cleaner Forklift truck Air compressor Overhead crane Lifting jacks

(3) Scale of Car Depot

The number of cars for the suburban railway may estimated by car depot, are as shown in the Table III-10-3.

Table III-10-3 Number of Cars by Depot

Car Depot	Line	1985		1995	
		Alternative-A	Alternative-B	Alternative-A	Alternative-B
Los Reyes	No. 1	153	135	213	174
Ecatepec	No. 3	114	90	141	114
Xalostoc	No. 2, 4, 5	285	234	390	327
Total		552	459	744	615

Table III-10-4. Scale of Car Depots

Car Depot	Name of Track Group	1985		1995	
		Alternative-A	Alternative-B	Alternative-A	Alternative-B
Los Reyes	Parking	$9^C \times 17^T$	$9^C \times 15^T$	$12^C \times 18^T$	$12^C \times 15^T$
	Daily inspection	9 x 2	9 x 2	12 x 2	12 x 2
	Monthly inspection	9 x 1	9 x 1	9 x 1	9 x 1
	Repair	2 x 1	2 x 1	2 x 1	2 x 1
Ecatepec	Parking	6 x 19	6 x 15	9 x 16	6 x 19
	Daily inspection	6 x 2	6 x 2	9 x 2	6 x 2
	Monthly inspection	6 x 2	6 x 1	9 x 2	6 x 1
	Repair	2 x 1	1 x 1	2 x 1	2 x 1
Xalostoc	Parking	9 x 32	6 x 19 9 x 14	9 x 44	9 x 37
	Daily inspection	9 x 3	9 x 3	9 x 4	9 x 4
	Monthly inspection	9 x 2	9 x 2	9 x 2	9 x 2
	Repair	2 x 1 1 x 1	2 x 1 1 x 1	2 x 2	2 x 1 1 x 1

Note: 1. C = cars, T = tracks

2. The number of cars in the column of parking track groups includes the cars that are parked outside the car depot.

As already mentioned, the inspections will be conducted on the provisionary inspection cycles until 1985. The planning of equipment and facilities at the time of inauguration is made so that the work volume of 1985 can be met.

The running kilometers per car in service will be 450 km/day to 490 km/day at the inauguration, and 510 km/day for 1995. The planning of equipment and facilities shall therefore be prepared on a time basis, with the annual working days set at 240 days.

Table III-10-4 shows the scale of individual car depot as estimated under the preconditions given above.

10-3. Workshop

10-3-1. Location and Scale of Workshop

The Workshop shall be designed to concentrate the equipment and facilities as much as possible and secure easy contact between the workshop and car depots. From this reason, the installation of one workshop near the Ecatepec Car Depot, is planned to locate it adjacent to one of the car depots to cope with the number of cars to be increased in future.

The scale of workshop is determined as described below.

The scope of work in the workshop are as followings including the items described in Table III-10-1.

(1) General inspection, main parts inspection, and the related repairs

(2) Inspections and repairs as incidentally required

(3) Utilization, control and repair of spare parts

(4) Manufacture and control of materials and parts produced and stored in the workshop

(5) Distribution of spare parts and stored goods to car depots

(6) Maintenance of facilities in the workshop and control of measuring instruments

(7) Investigation and draw up of countermeasures against troubles of rolling stock

To perform these jobs for the whole railway lines, the workshop needs to have the facilities and engineering personnel centralized in one place to cope with the possible future increase in the number of cars.

Fig. III-10-1 illustrates the relations between the expected number of cars by fiscal year and the number of cars handled in the workshop for inspection and repair.

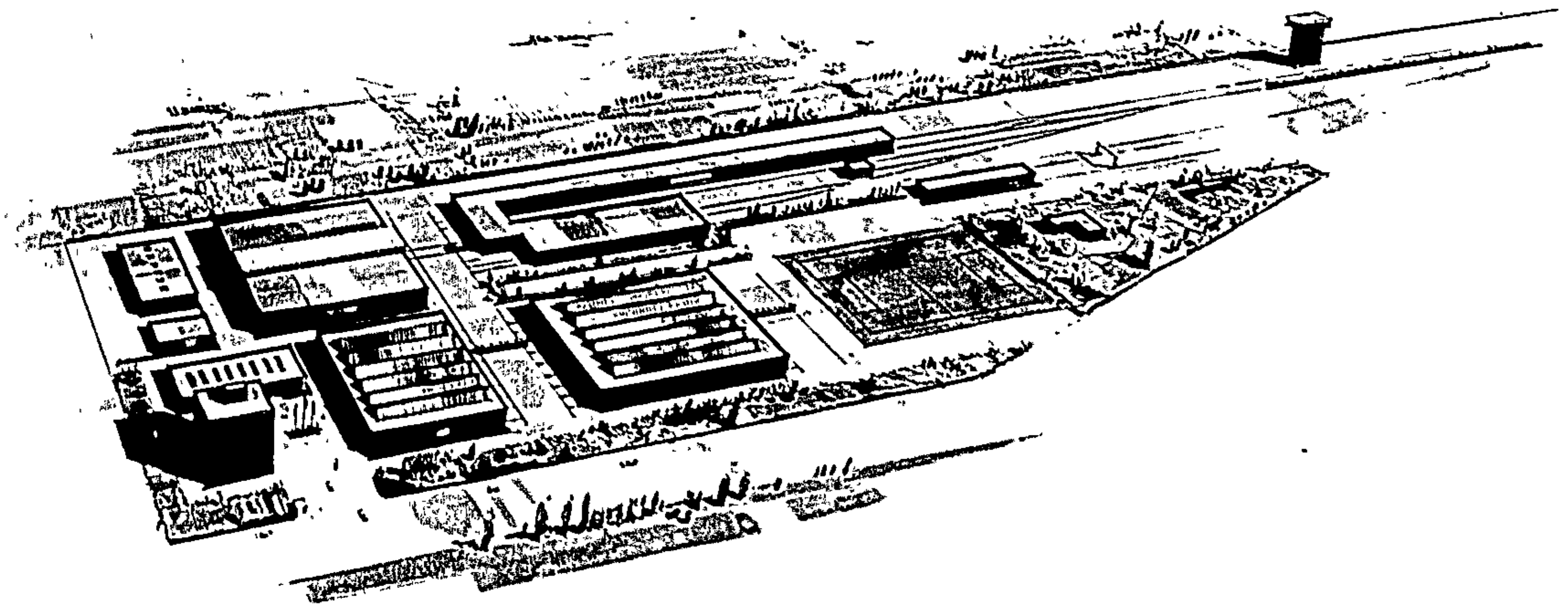
The calculation of the number of cars to be handled at the workshop for inspection and repairing work was made based on a provisional period as given in Table III-10-1 for the years 1982 to 1989, and on its proper period for 1990 and after.

The Figure shows that the number of cars handled at the workshop decrease in spite of increase in the number of cars in service. This is because the inspection cycles are prolonged. But the actual transition from the provisional period to the proper period is not made at a time, but is considered to be made gradually and the number of cars handled at the workshop will be averaged yearly.

These data show that the workshop can do with the scale of 250 cars handled annually for inspection and repair initially in 1982 (approximately one car per day), approximately 370 cars (1.5 cars per day) in 1985, and about the same in 1995.

The scale of equipment and facilities in the workshop as planned for initial operation, if set at about 400 cars to be handled annually (1.5 cars per day), will satisfy the needs for 1995. The planning shall be such which will permit the enlarging of the scale to cope with the increase in number of cars accompanying the possible future extension of the railway route.

In this Project, consideration is given to the possible total number of cars up to approx. 1,500 cars (750 cars to be handled annually at workshop) with respect to the scale of the workshop to meet the purpose.



Ecatepec car Repair Workshop

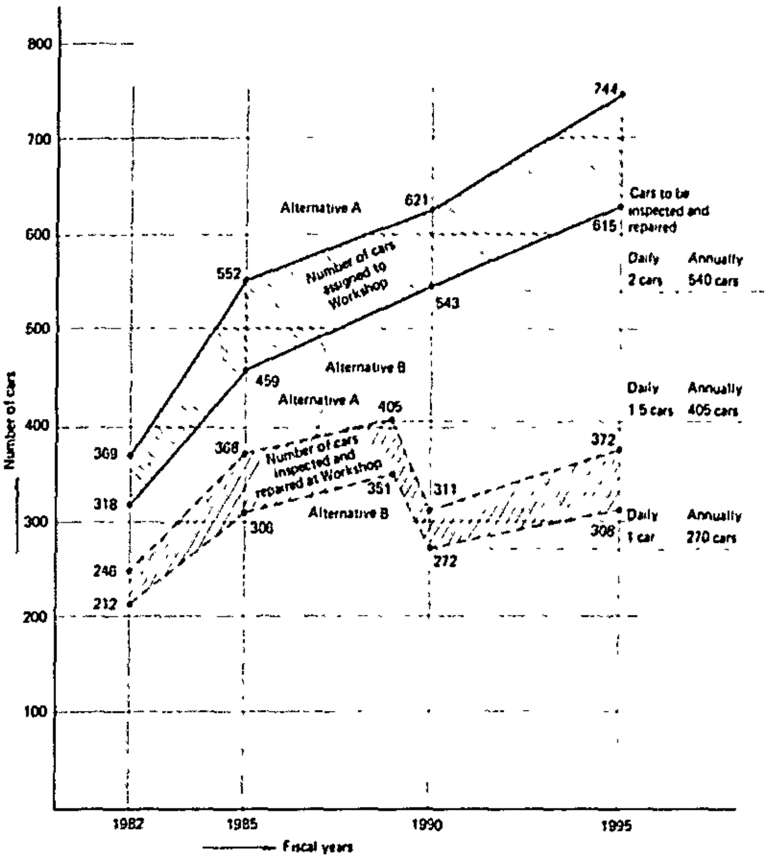


Fig. III-10-1. Number of Cars Assigned to Workshop and Number of Cars Inspected and Repaired at Workshop, by Fiscal Years

10-3-2 Flow of Inspection and Repair Work

To determine the workshop layout, the flow of inspection and repairing operations shall first be taken into account, by classifying the processes into three categories as shown in the Table III-10-5 for individual and independent control, with the following intentions:

(1) The cutting down of the number of days needed for inspection and repair through rationalization and standardization of the work

(2) Prevention of fluctuations in parts repairing work, and effective use of personnel and workers

(3) Specialization of production of materials and parts produced and stored in the workshop.

Table III-10-5. Classification of Work Process

Classification	Description
1st Process	Process for the inspection and repair of car body, and of equipment and devices as installed on car body
2nd Process	Process for the inspection and repair of equipment and devices dismantled from car body
3rd Process	Process for the manufacture of such component parts and materials needed for the 1st and 2nd processes

An electric car is divided into the following parts:

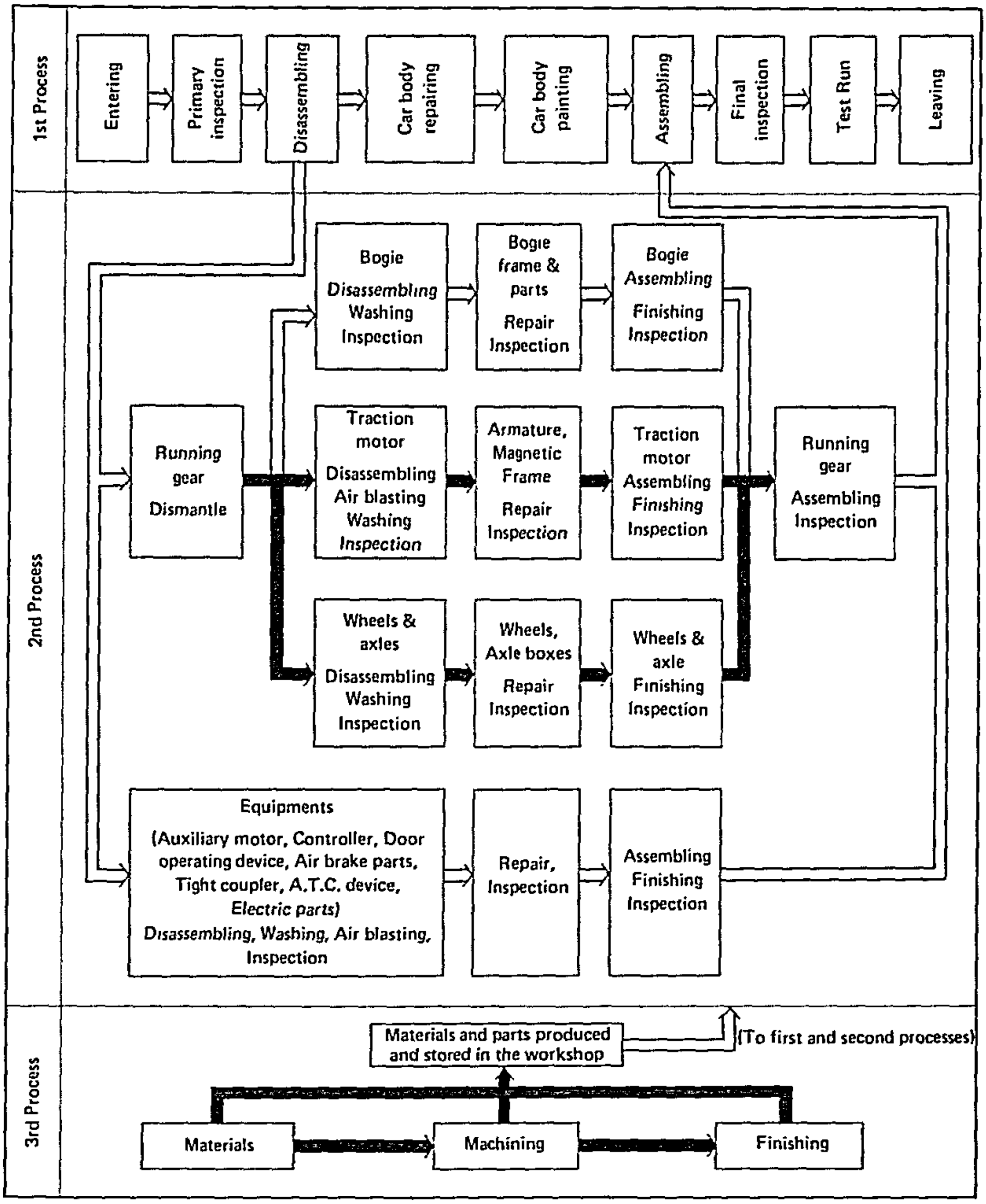
1) Car body and interior equipment
2) Car body pipings and wirings to make each device function
3) Running gear and brake system
4) Other devices and equipment installed on car body

Each item differs in the time and days required for the inspection and repair.

For this reason, the processes are classified into three categories: 1st Process, work on the car body (items 1 and 2 above, and dismantling and remounting of parts), 2nd Process for the work of inspection and repair of parts, which needs complicated inspection and repair requiring a long period (items 3 and 4 above) and in which the spare parts are stored, with corrections and repairs made in advance, to be supplied to the work on the car body, and 3rd Process which is in charge of the manufacturing parts and materials required for 1st and 2nd processes, and in which such parts and materials are to be manufactured independently of the repairing process, through the process control for keeping its proper quantity of regular stock. Fig. III-10-2 illustrates the flows of work by processes.

10-3-3. Inspection and Repairing Work Processes

To draw up the rolling stock inspection and repair plan, it is necessary to settle in advance the daily schedule of work for each inspection site, that is, the standard process, and thus conduct the inspections and repairs on a planned basis. This forms an important part of the car turnaround program, the operation of cars, and the planning of the inspection and repairing facilities, and personnel plan.



Note: ➡ indicates the flow not directly affected by the first process.
In the second process, recirculated spare parts are to be used.

Fig. III-10-2. Flow of the Work of each Process

The preparation of the standard processes has close relations with the details and level of the work, and available facilities and personnel. Further the repairing work, because of its proper nature, has variations in its details for different cars even in case of the same inspection classification, and also has variations in the level of skill of workers.

These processes should be shortened as far as possible from the viewpoint of effective use of cars, but at the beginning of the new railway operation when few cars are expected to enter into inspection, it is also necessary to consider the adoption of somewhat prolonged processes because of the inability to make efficient use of personnel owing to big fluctuations in the work and from the standpoint of the accumulation of skills for inspection and repair, and then shoten the processes gradually with the increase in the number of cars put to inspection and repair for better car utilization and efficient use of workshop facilities.

Thus the Standard Processes have been settled as illustrated in Fig. III-10-3, taking into account the actual service results in Japan and the circumstances in Mexico. The Figure also includes the cases of inspection of 2 and 3 cars per day, which are given for the calculation of the scales of facilities to meet the future increase in the number of cars.

The Table III-10-6 shows the required particulars of principal equipments and facilities of the Workshop as required by such processes.

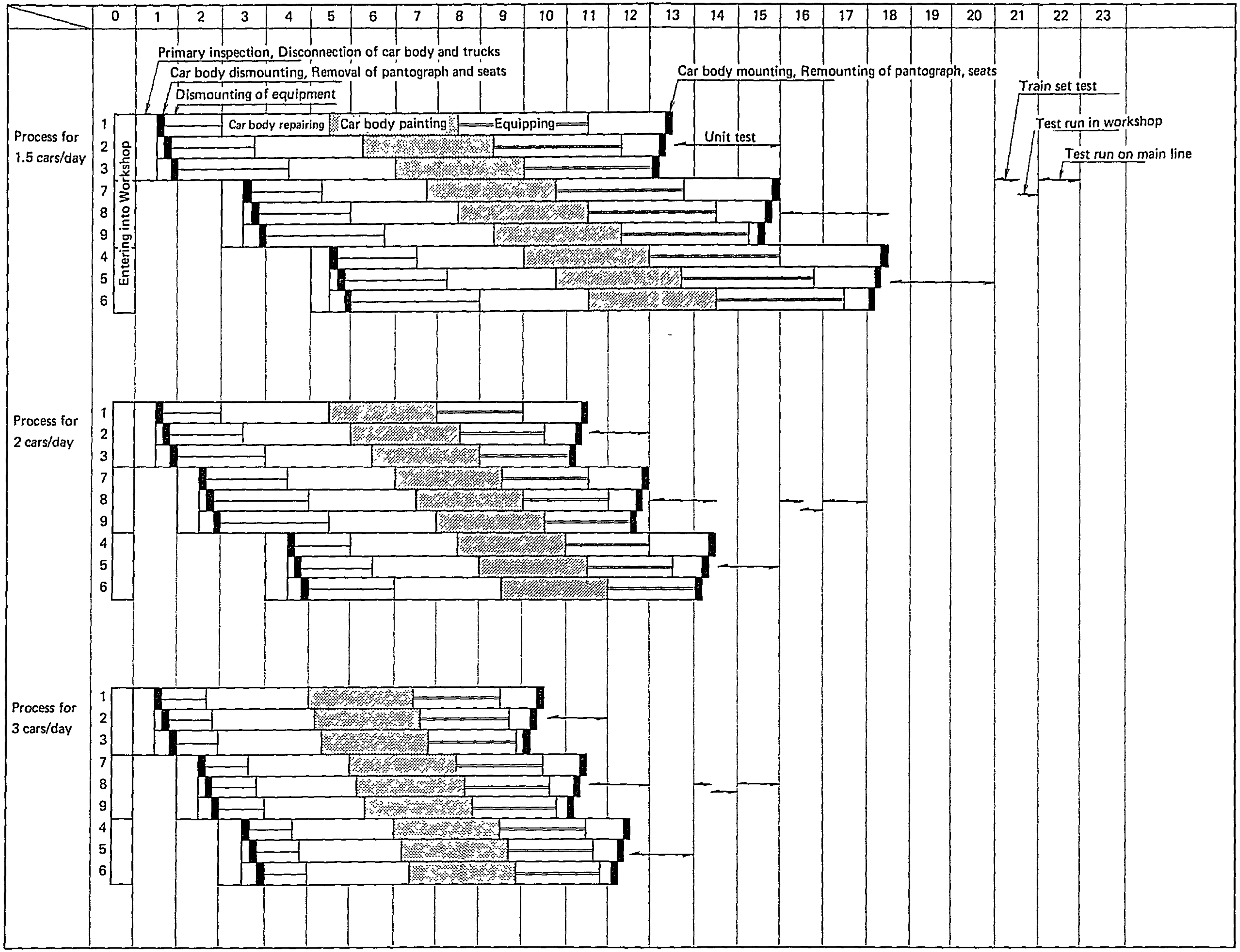


Fig. III-10-3. Standard Process Schedule for Inspection and Repair at Workshop

Table III-10-6 Required Particulars for Principal Facilities of Workshop

Number of cars treated	1.5 cars/day	2 cars/day	3 cars/day
Primary & Final Inspection Shop	$3^{C/T} \times 2^{T}$	$3^{C/T} \times 2^{T}$	$3^{C/T} \times 2^{T}$
Car Body Dismounting/ Mounting Shop	1 x 2	1 x	1 x 2
Equipment Disassembling Shop (on-roof, underfloor)	1 x 2	1 x	2 1 x 2
Car Body Repair Shop	3 x 3	3 x	3 x 4
Equipment Assembling Shop	1 x 6	1 x	1 x 9
Car Body Painting Shop	3 x 2	3 x	3 x 3
Train Adjustment Shed	9 x 2	(12) 9 x	(12) 9 x 2
Extra-inspection & Car Body Lifting Shop	1 x 1	1 x	1 x 1
Extra-inspection & Repair Shop	3 x 2	3 x	3 x 2
Max. Number of Cars Staying in Workshop	36^{C}	36^{C}	45^{C}

C/T = cars/track, T = tracks, C = cars

10-3-4. Facilities for Inspection and Repair

(1) Fundamental Concept of Inspection and Repair Work and Facilities in Workshop

1) Car bodies shall be moved on temporary-use trucks and traverser, and not by overhead crane.

2) The works of similar operational details shall be performed at the same place.

Example: Car body lifting and lowering, disassembling of equipment, car body repairing, etc.

3) The works of wholly dissimilar operational details shall be separated.

Examples: Car body repairing and car body painting, etc.

4) Equipment or parts, not many in quantity, but requiring many kinds of operations shall be processed at a fixed place.

Example: Trucks, electric equipment, etc.

5) Equipment or parts, comparatively many in quantity, and handled in a regular order of operations shall be processed with the Tact System to enhance the efficiency.

Examples: Wheels and axle inspection and repair, future car body painting, etc.

6) The working sites having close relation directly with each other shall be combined together organically to strengthen their facilitate mutual adjustment.

Examples: Among the inspection and repairing shops of trucks, wheels and axles, and main motors, one with another, and between assembling shop and parts inspection and repairing shop, etc.

(2) Method for Operations at Each Operating Shop

1) Access to the Workshop can be made in train sets, and the decomposition and making up of train set by handling unit consist shall be made in the train adjustment shed.

2) Primary and fainal inspections shall be made in as-assembled state on the pit line, and the on-roof equipment and interior installations (seats etc.) shall be removed or remounted before the dismounting and mounting of the car body.

3) The dismounting and mounting of car body and trucks shall be made by lifting and lowering with lifting jacks. The incoming car will have its car body mounted on temporary-use trucks to be transferred to the next shop for disassembling of equipment and will have its bogie trucks transferred to the truck inspection and repair shop on traverser.

4) The disassembly of component parts from car body shall be performed at the same place as the car body repairing work, with the car body fixed at one place. The disassembly of heavy components shall be performed with the aid of mechanical power. Repairing of car body and roof shall be made on raised scaffolding.

5) The car body painting, that is, a series of interior cleaning, car body rubbing, masking, painting and drying, shall be made by Tact System in future. Even at the beginning the painting shall be performed in the specialized painting shop considering environment of the workshop.

6) The disassembling and reassembling of a bogie truck is to be made at the fixed position, using an overhead crane, and wheels and axles and main motors are to be sent to respective inspection shops. Bogie frame, bolster, axle springs, etc., after cleaned, shall be inspected with instruments, repaired, painted, dried and then led to reassembling process. Magnetic flaw detector shall be provided for flaw detection of these components.

7) Continuous flow process shall be applied to the normal inspection and repairing work for the wheels and axles, such as dismantling of axle boxes, cleaning of wheels and axle, non-destructive test, cleaning of gear boxes, wheel tread milling, remounting of axle box, flushing, etc. The major repairing operations for the replacing of wheels, axle, gear, etc., shall be effected in a separate working place, by a fixed-position system. The inspection and repair of axle boxes shall be performed at an independent operating shop for dismantling, cleaning, instrumental inspection, repair and reassembling.

8) The main motor, after air blasted, is dismantled into magnetic frame, armature etc., and then, after cleaned, is subjected to inspection measurements such as magnetic and ultrasonic flaw detection, electric measurements etc., and further is reassembled after repairing,

painting and drying, and finally is confirmed and checked for the characteristics and functioning through the prescribed inspection tests. Such major repairs as the rewinding of the binding wire and varnish re-pregnation must be practicable in the Workshop.

9) The electric and mechanical parts of the car shall be dismantled, inspected and repaired, and reassembled, after washing or air blasting to suit the characteristics. After the reassembling, it shall be subjected to a single-unit motion test as required to confirm the functions and characteristics.

10) The machining work of the parts shall be performed on a centralized basis, and the welding and filling work of the parts, occurring comparatively frequently, shall also be centralized.

11) The cars shall be subjected to comprehensive test on an individual unit after assembled completely for the comprehensive confirmation and adjustment of the functions and performance characteristics, and shall be subjected to the trial runs on the premises and on the main line after formed into a train.

The unit test shall be conducted for the comprehensive confirmation of motions and functions such as electric circuit control, brake control and ATC functioning etc.

The test run on the premises shall be conducted as a preparatory step to the main line test run mainly for the confirmation and adjustment of accelerating and decelerating conditions, spark condition of commutator brushes of main motors, conditions of combination of component parts, controll conditions, etc.

The main line test run shall be conducted on the actual main line, based on a train schedule set in advance, for the confirmation of final functions and performance characteristics such as acceleration and declaration, ATC functioning, maximum speed, vibration of the car, heat accumulation of the motors, etc.

12) The maintenance and management of workshop inspection and repairing facilities, measuring instruments and apparatus, jigs and tools shall be conducted within the Workshop itself through periodical checking and adjustment.

Table III-10-7 shows a list of principal equipment and facilities considered necessary to the Workshop from the abovementioned viewpoint.

Table III-10-7 Workshop Facilities

Name of Shop	Description of Facilities
Primary & Final Inspection Shop	Test equipment for electric circuits ATC test equipment Air brake test equipment, etc.
Car Body Dismantling & Mounting Shop	Lifting jacks Temporary-use trucks and their movers Monorail hoist and carring device
Disassembling & Assembling and Car Body Repair Shop	Equipments for removing, refitting and carrying underfloor components Electric arc welding machines Machines for processing the pipings etc.
Car Body Painting Shop	Car body painting equipment Paint drying equipment etc.
Truck Inspection & Repair Shop	Overhead cranes and other carriers Bogie and parts cleaning equipment Bogie painting equipment Magnetic flaw detector etc.
Wheels and Axle Inspection and Repair Shop	Overhead cranes and other carriers Cleaning equipment for respective wheels and axle component parts Oil flushing device Ultrasonic and magnetic flaw detectors Lathes etc., for wheels and axles Wheels and axle fitting presses etc.
Electric Components Inspection and Repair Shop	Test equipment for high-voltage equipment and control equipment Main thyrister test equipment ATC device test equipment Speedometer test equipment Testers of individual electric components Pantograph inspection and repairing equipment, etc.

Main Motor Inspection and Repair Shop	Overhead cranes, other carriers Individual rotators test equipment Electric insulation test equipment Ultrasonic and magnetic flaw detectors Devices for removing and refitting of pipings, etc. Armature lathes, etc. Dynamic balancing machines Binding machine Varnish re-impregnation equipment Drying furnace, etc.
Brake Parts Inspection and Repair Shop	Air brake parts testing machines Cleaning devices of individual parts Painting and drying equipment Door operating device inspection and repairing equipment, etc.
Machining and Ironwork Shop	Various kinds of lathes Various machining equipment Heating furnace Air hammer Tight-lock coupler inspection and repairing equipment Steel plate processing machines etc.
Common-use Equipment	Traversers Shunting locomotive Boilers Air compressors Electric power souce facilities Gantory cranes Carrier vehicles

10-3-5. Fundamental Layout of Workshop

The layout of workshop shall be studied and reviewed for the most suitable layout after the construction site is decided. Now that the construction site is not decided yet, the layout is worked out as shown an Appendix Fig. III-10-4, chiefly with a view to meeting the flows of inspection and repairing work and the possibility of future enlargement of facilities.

The required land area will be about 190,000 m^2, sufficient for the inspection and repair of the possible future assignment of about 1,500 cars, if calculated on the basis of actual service results in JNR and supposing the building-to-land ratio as 25%.

The following points are taken into consideration for the layout of each shop:

(1) Train Set Adjustment Shed

This will be provided with one incoming track and one outgoing track, where a train is divided into individual cars, and cars are united together to form a train set. Here, cars are subjected to the unit test and the train set test at the time of leaving the workshop. For these purposes trolley wires, inspection pit and inspection stand shall be installed. At the beginning of the workshop the entering shall be made by 9-car train set, but the facilities are planned to have a space for the future extension to permit the entering of 12-car train set.

(2) Primaly and Final Inspection Shop

There shall be provided two tracks, one for incoming and the other for outgoing, each having the effective length equal to 3 cars, together with trolley wires, inspection pit, and inspection stand.

(3) On-roof Equipment Disassembling and Assembling Shop

An overhead crane shall be installed for the centralized work of dismantling and remounting such on-roof equipment as pantograph, vacuum circuit breaker, ventilator, etc.

(4) On-roof Equipment and Interior Equipment Inspection and Repair Shop

This is the shop for those which are to be dismantled or remounted in the shop referred to in item (3) above, and shall be located as near to the shop of (3) as possible.

(5) Disassembling and Car Body Repairing Shop, and Extra-inspection Repair Shop

The dismounting of car component parts and the repairing of the car body shall be performed within the same working shop and by the fixed-position system. The 2 tracks of 3-car repair shop shall be installed as Extra-inspection Repair Shop for Extra-inspection and repair or remodeling work, generally adjacent to the Car Body Repair Shop so that such tracks may take the charge of the work of the adjacent shop in case when the work schedule becomes too busy.

(6) Car Body Painting Shop

The car body painting shop, provided with 2 tracks each for 3 cars at the initial period, shall not take complete Tact system, but the painting, drying, masking, etc. shall be performed in exclusive shop. A sufficient space is secured so that the continuous flow process system may be applied, with the increase of the number of cars inspected and repaired, even to multi-color painting.

(7) Assembling Shop

The work for fitting the car component parts to the car body is made convenient in transferring of parts and by close linking in processes, through the layout of specialized assembling shop and the parts repairing shop in the same building. The assembling work has many elements of fluctuation in the process, and it is so arranged that cars can be stored, one by one, facing the main traverser, for swift response to such fluctuation.

(8) Parts Inspection and Repairing Shop

This shop shall be located within the same building with the Assembling Shop described in the item (7) above, and is arranged so as to permit the expansion together with the Shop of (7) with the future increase in the number of cars to be inspected and repaired.

(9) Inspection and Repair Shop for Trucks, Wheels and Axles, Main Motors, etc.

On the extension of two tracks of the Dismounting and Mounting Shop, there shall be installed to Truck Dismantling and Reassembling Shed, around which a series of shops relative to trucks, such as bogies, wheels and axles, main motors, etc., are to be arranged with the intention of strengthening the linkage of various operations and facilitating their control.

(10) Installation of Traversers

There are provided two traversers, main and auxiliary. At the beginning of the railway inauguration when there are only few number of cars subjected to inspection and repair, one traverser will be enough for the purpose, with little working hours. But, the adoption of the Tact System for preservation of the environment of the Car Body Painting Shop will necessitate the auxiliary traverser. It is planned that this auxiliary traverser can be used with relation to the Car Body Repair Shop, not limiting it to the exclusive use for the Painting Shop.

(11) Ironwork and Machining Shop

Ironwork operations such as steel plate cutting, folding, welding, metal filling and other processing, forging, and coupler inspection and repair work as well as the machining of car component parts, maintenance and manufacture of tools, and the manufacturing of maintenance parts of workshop facilities shall be centralized, with the possibility left for the future expansion of the facilities.

(12) Other Facilities

Further, based on the experiences in JNR, there shall be provided such operational facilities as power house, supplies warehouse and management office as well as welfare facilities for employees such as locker rooms, shower rooms, canteen, having a space sufficient for athletic field.

10-3-6. Timing to Adopt Two-shift System

The service system in railway workshops usually adopt day service, but there is an example of two-shift service in Mexico. Some review has been made on the time for moving to the possible two-shift service system.

Generally speaking, the purposes of two-shift or three-shift service system in manufacturing workshops exist in the following points, even with a little difference depending upon the types of work, excluding the case of iron and steel production in which the continuous operation is obligatory:

(1) Increase in production with the same facilities

(2) At peak periods in heavy production fluctuations

(3) Continuous production for faster depreciation of facilities urged by the necessity for earlier updating of the facilities in the field of admirable technical innovation

(4) A large heat loss unless continuously operated

(5) Increase of production in a certain working section which may otherwise cause a bottleneck to the production system as a whole.

To execute such service system, it is required to take various measures and put them into practice.

Such inspection and repairing works as in railway workshops include a very small amount of the same types of simple services occurring repeatedly and alarge amount of services requiring the judgement by skilled operators. Such works will have frequent fluctuations in the details of the work and the difficulty in mutual communication for the continuance of such services and in the putting of the responsibility system into practice.

For these reasons, there is difficulty in practicing the multiple shift services.

The facility investment for the workshop in this Project is limited to the minimum needed for the execution of the inspection and repairing operations, without multiplying the quantity of equipment for production increase.

The time for adopting the multiple shift services will be set at the time when the work volume has exceeded the capacity of the facilities to avoid the increasing of the investment.

If such shift is effected at such time as the initial period of inauguration having only small work volume, then the loss in the effective use of personnel because of big fluctuation in the work will be far heavier than the benefit obtained by the decrease in the number of cars out of service resulting from shortened stay in the workshop.

3 cars/day inspection and repair will be a level point against the presently planned facilities. At the time when this work volume is exceeded, that is, when new investment is needed in full scale, it is recommendable to move gradually to the multiple shift services, beginning with operations suited to multiple shift, such as car body painting, main motors, wheels and axle inspection and repair, selecting comparatively simplified work process, taking into account the amount of investment on the facilities.

11. Construction Plan

11-1 Rough Estimation of the Construction Cost

Rough estimation of construction cost is made in consideration of the data (Labor cost, Material unit price, etc.) supplied by Mexican side, and actual results of constructions in Japan, and by setting the following conditions, assuming the labor productivity of both countries to be the same.

1) Civil engineering

(1) Problems arising from the special characteristics of Mexican-clay in execution of works and extra wages in consideration of the working environments are not considered.

(2) The roadbed construction cost of Line 5 is assumed to be the same as the average value of per Km construction costs of the Line 1 through the Line 4.

(3) Rails, turnouts and their attachments are assumed to be imported.

(4) Land purchasing cost, indemnity for properties are not included.

2) Electricity

(1) Electric equipments for 230 KV or over, special equipments for 25 KV AC-electrification, and materials for trolley wires are assumed to be imported.

(2) Ninety percent of the materials for signal and telecommunication are assumed to be imported.

(3) All engineers and labors for installation works are assumed to be locally employed.

3) Machines and Instruments

(1) All machines for inspection and repair of rolling stock are assumed to be imported.

(2) All escalators are assumed to be imported.

(3) Automatic ticket vending equipment and automatic ticket examining equipment are assumed to be imported at the initial stage gradually transferring to the domestic production with the ratio of;
20 % in 1985, 30 % in 1990, 30 % in 1995.

(4) All engineers and labors for installation works are assumed to be locally employed.

4) Rolling Stock

(1) All the rolling stock are assumed to be imported initially, then gradually transferred to the domestic production with the ratio of; 20 % in 1985, 30 % in 1990, 35 % in 1995.

(2) The value of spare parts for the rolling stocks shall be 7 % of the value of the rolling stock at the opening of business and 2 % thereafter.

Table III-11-1 indicates the break down of the rough estimation of construction costs.

Incidentally, additional investment is not included in the table.

Table III-11-1 Rough Estimation of Construction Costs

(Unit: million pesos)

Item	Alternative-A	Alternative-B
Civil Construction	9,022	7,821
Electric Power	2,221	1,395
Signal, Telecommunication	1,731	1,416
Car Depot	1,327	1,296
Rolling Stock	6,107	4,952
Total	20,408	16,880

Note) Alternative-A includes also the construction costs related to A.T.O.

11-2 Construction Schedule

Two cases are considered; to open all the lines simultaneously and to open by stages.

Table III-11-2 indicates the schedule of opening all lines at the same time. The schedule intends to complete the project as early as possible from on the following considerations:

11-2-1 Civil Engineering Work

Among the civil engineering works, what require long period of time are, construction of grade separation, rolling stock depot and stations. Especially, construction of grade separation will govern the whole construction terms. It will take about one year to construct one grade separation although this depends on its scale and conditions. Consequently, in order to complete all civil engineering works within about two years, the total 77 Km shall be divided into the work sections of about 4 Km length taking the balance of volume of works, such as number of grade separations and number of stations, into consideration. Further, all the work sections shall start construction works at the same time.

Table III-11-2 Schedules for Simultaneous Opening of All Lines

Kind of work	1978		1979		1980		1981		1982	
Preparation of contract	////									
Detailed designing Tender		////								
Civil construction			////	////	////	////				
Track facilities					////	////	////			
Electrical facilities				////	////	////	////			
Rolling stock						////	////	////		
Testing								/		
Train operation for training								////	Opening	

11-2-2 Track Construction

Track constructions in Mexico seem to have been performed in the order: (1) to spread ballast after completion of roadbed, (2) transport sleepers and lay them on the ballast at the specified interval, (3) transport rails and fasten them to the sleepers, and then (4) spread upper ballast to complete the track. In this project, however, with the aim to reduce the construction term, three construction depots are planned in rolling stock yards where track-skeletons are to be assembled by machine. Track-skeletons are transported to construction sites from the construction depots, and track construction works will be promoted by laying skeletons one after another.

In this way, track construction works are to be completed in about 5-months after the completion of roadbed.

11-2-3 Construction of Electric Facilities

The construction of electric facilities is scheduled to complete within about 3-months after the completion of track construction.

11-2-4 Tests

After completion of construction work, following tests shall be necessary; those are speed-up test, various tests of electric instruments (track circuit test, pressure test, A. T. C., etc.), tests of rolling stock inspection and repair equipments and their agings. The term for the above tests is set to be 2 months.

11-2-5 Educational Operation

Crew and other workers for inspection and repair shall be trained and practiced to maintain regular operations and to minimize troubles after inauguration. The training period is scheduled to be 4 months.

According to this general schedule, at least 3-year period, after starting the construction, is considered necessary for the completion of this total projects.

In the case of step by step inauguration, conditions are eased in terms of finance and construction period compared with the case of simultaneous inauguration of total lines. Moreover the training schedule of crew and other employee can be carried out step by step, and the contents of each training program are simplified and making the education scale smaller, thus overcoming the problems of inauguration works smoothly.

12. Estimate of Revenue and Expenses and Financial Analysis

12-1. Capital Cost

The capital cost of this project is estimated in accordance with the descriptions made in the preceeding chapters.

12-1-1. Initial Capital Cost

(1) General Description

The total capital cost, including interest during the construction period up to the commencement of business operations, is estimated for both Alternative-A and Alternative-B as shown in Table III-12-1.

Alternative-A	25. 0 billion pesos (US$1, 088 million)
Alternative-B	20. 7 billion pesos (US$ 902 million)

Table III-12-1 Initial Capital Cost

(In millions of pesos)

	Alternative-A	Alternative-B [Base Case]
Civil Construction	9,022 (1,595)	7,821 (1,104)
Electric Power	2,221 (891)	1,395 (523)
Signal, Communications	1,731 (1,514)	1,416 (1,240)
Car Depot	1,327 (479)	1,296 (479)
Rolling Stock	6,107 (6,059)	4,952 (4,910)
General Management Expense	1,691 (-)	1,436 (-)
Sub Total	22,099(10,538)	18,316 (8,256)
Interest During Construction	2,924 (-)	2,425 (-)
Grand Total	25,023(10,538)	20,741 (8,256)
(in US$)	1,088 (458)	902 (359)

Note: Figures in ( ) indicate foreign portion.

Among the various items, civil works and rolling stock are the major items in the initial capital cost.

In the estimate of initial capital cost the proportion of the foreign portion to the local portion is high for rolling stock, signals and telecommunications where we assume that most of the requirements will need to be imported. The foreign portion of civil works is mainly for the importation of rails.

The calculation was made on the assumption that the fund for the foreign portion would be provided chiefly in the form of suppliers' credit co-financed by the Export-Import Bank of Japan and commercial banks in Japan (Details are given in section 12-2.)

(2) Bases of Calculation

For the procurement of required materials and mechanical equipment efforts are made for the domestic procurement to meet the Guide Line of the Mexican Government to hold down imports from overseas to 45% or less.

The foreign portion of the initial capital cost indicates the funds required to procure and import foreign made materials and mechanical equipment (on the base of CIF as of 1977). The balance is the local portion for the materials and mechanical equipment to be procured in Mexico and the construction cost including installation cost. The calculation is based on the data obtained by the survey made in Mexico as far as possible and otherwise from data obtained in Japan.

The currency is shown in pesos, with the rate of exchange assumed to be US$1 equalling 23 pesos and US$1 equalling ¥250.

Cost escalations during the construction period are not taken into account. (Escalations are treated in section 12-4 Profit and Loss, Cash Flow Projections.)

For details of interest costs during construction, please refer to section 12-2 Financing Plan.

12-1-2 Additional Capital Cost after Inauguration

The additional investments forcasted after the commencement of business are incurred mainly to meet the increase in the volume of transportation. The rolling stock which constitutes the larger portion of this investment is assumed to be imported initially. However, it is considered feasible to gradually transfer to locally produced cars for additional requirements.

Therefore, additional capital costs are not itemized into either the foreign portion or the local portion. Rather, these funds are expected to be raised out of the project's cash flow after the commencement of business operations.

The total amount of additional investment is assumed to 7.2 billion pesos for Alternative-A and 5.1 billior pesos for Alternative-B. (Table III-12-2)

Table III-12-2 Additional Capital Cost after Inauguration

(In millions of pesos)

	1982-1986	1987-1991	1992-1996	Total
Civil Construction	418 238	209 175	206 101	833 514
Electric Power	46 24	214 149	- -	260 173
Car Depot	- -	19 19	19 19	38 38
Rolling Stock	2,858 2,146	1,115 1,067	1,695 926	5,668 4,139
General Management Expense	204 141	90 79	118 64	412 284
Total Alternative-A Alternative-B	3,526 2,549	1,647 1,489	2,038 1,110	7,211 5,148

For each item; Upper line = Alternative-A, Lower line = Alternative-B.

12-2 Financing Plan

In this project, decisions relating to the selection of financing sources and the scheduling of repayments are complicated problems which require considerable experience and technical knowledge. It is of great importance, therefore, to obtain the close cooperation of the related financial institutions and to work out adjustments among the parties concerned to raise the needed funds.

Generally, the financing plan for this type of large scale project is composed of components such as shareholders' equity, shareholders' loans (subordinate loans), export credits, bank loans and the issuance of bonds. The percentage shareholders' equity occupies in the total required fund has a vast influence on the ability to obtain loans and to attain a proper ratio of liabilities to own capital, on the operating expense and required revenues for the project, and on the cash flow.

However, for this project the initial capital cost (including interest during the construction period) is planned to be raised entirely through external debt in accordance with the request of the Mexican side. Debt financing of this extent is premised on the availability of a guarantee of the Mexican Government to facilitate raising the funds. Consequently, the raising of funds through equity investments by the Mexican Government is not considered at this time.

Also, funds from international organizations such as the World Bank and IDB have been excluded at the suggestion of the Mexican side.

In view of the fact that the initial capital cost is enormous and the funds must be raised efficiently, various sources of funds are combined to make the best use of their respective characteristics.

The following four types of funds are assumed herein;

(1) Export Credit (Suppliers' Credit)

These cover 85% of the foreign portion (materials and equipment to be imported), and the cost of installing equipment at the site (which equals 15% of the value of the imported materials and equipment). Repayment starts 6 months after the commencement of business and is to be made in 20 equal semiannual installments. A fixed rate of interest of 7.5% p.a is assumed.

(2) Syndicated Loan

The funds to be supplied by the syndicated loan are equal to the balance of the initial capital cost (including interest during the construction period) remaining after other sources such as suppliers' credit, etc., have been obtained.

The loan(s) will be disbursed each year during the three year construction period. Each years disbursements will be consolidated and will be repaid in 8 equal semiannual installments commencing after a 3-year grace period. Interest rates for this loan will fluctuate depending on the rates in the Eurodollar market and the long term yen rate in Japan. However, for calculating profit and loss and cash flow projections, a rate of 8.75% p.a. has been used (the weightened average interest of the combined Eurodollar and Japanese yen rates) which seems practicable viewed from the present situation. Although it is more realistic to anticipate floating interest rates, fixed interest rates have been assumed in estimating the profit and loss and cash flow projections explained in section 12-4.

(3) Railway Bond

Amount: 2.3 billion (corresponds to approximately US$100 million)

Term: 10 years (including a 5-year grace period)

Redemption of the bond will commence 5 years after it is issued.

A coupon rate of 7.5% p.a. is assumed (excluding commissions and fees).

Similar bonds already have been issued by the Mexican Government. In addition to issuing yen bonds in the Tokyo market, the issuance of US-dollar bonds elsewhere warrants further study.

(4) Government Assistance/Additional Loans

Assistance from the Mexican Government or additional loans are techniques which could be used to supplement cash flow deficits after commencement of the project.

The "Base Case" referred to in paragraph 12-4-1 assumes that the Government will assist in meeting cash flow deficits by providing non-interest bearing loans which will be repaid out of future cash surplus.

Of course additional medium and long-term working funds to cover cash flow deficits also could be obtained from domestic or international non-governmental sources.

Summary Financing Plan

(In millions of pesos)

	Foreign Portion	Local Portion	Interest During Construction	Total
Alternative-A				
Export Credit	8,957	1,581	-	10,538
Syndicated Loan	1,581	7,680	2,924	12,185
Railway Bond	-	2,300	-	2,300
Total	10,538	11,561	2,924	25,023
Alternative-B				
Export Credit	7,018	1,238	-	8,256
Syndicated Loan	1,238	6,522	2,425	10,185
Railway Bond	-	2,300	-	2,300
Total	8,256	10,060	2,425	20,741

In Japan, normally national or local governmental entities offer subsidies for this type of railway, which is illustrated in Table III-12-3.

Table III-12-3 Railway Construction Subsidy System in Japan

Enterpreneur	Classification of Subsidy	System of Subsidy
National Railway	Subsidy for the construction of transportation facilities in large cities	For reorganizing transportation facilities to improve and increase the transportation capacity in large cities, subsidies of 30% of the construction cost are granted by the Government.
Private Railway	Subsidy for the construction of subways	To reorganize or improve subways in large cities, 66% of the construction cost will be granted as a subsidy, which is borne by the Government and local public entities evenly, and is paid in 6-year installments.
	Subsidy for the construction of railways to New-Town	For the construction of New-Town railways of public or quasi-public management, 36% of the construction cost will be granted as a subsidy, which is borne by the Government and local public entities evenly, and is paid in 4-year installments.

12-3. Operating Revenue and Expenses

12-3-1. Operating Revenue

The revenue naturally depends on the fare policy, and the plan is based on the traffic demand estimates explained in section III-3, and the operating revenues are calculated for the first 15 years of operations based on uniform fares of 3 pesos, 4 pesos and 5 pesos (Table III-12-4).

In practice, miscellaneous incomes from advertising, public information leases, etc., can be expected, but they are excluded from this calculation.

Table III-12-4 Estimation of Operating Revenue

(In millions of pesos)

Year	Users Per year (million)	Yearly Operating Revenue on Uniform Fares of;		
		3 pesos	4 pesos	5 pesos
1982	590	1,770	2,360	2,950
1983	701	2,103	2,804	3,505
1984	812	2,436	3,248	4,060
1985	923	2,769	3,692	4,615
1986	959	2,877	3,836	4,795
1987	995	2,985	3,980	4,975
1988	1,031	3,093	4,124	5,155
1989	1,067	3,201	4,268	5,335
1990	1,105	3,315	4,420	5,525
1991	1,141	3,423	4,564	5,705
1992	1,177	3,531	4,708	5,885
1993	1,213	3,639	4,852	6,065
1994	1,249	3,747	4,996	6,245
1995	1,287	3,861	5,148	6,435
1996	1,323	3,969	5,292	6,615

12-3-2 Operating Expenses

Operating expenses for each department are classified into material and personnel expenses, each of which are further classified into sub-items, and are estimated item by item for cumulative calculation.

The yearly average operating expenses for the respective items are shown in Table III-12-5.

Basic Assumptions

All calculations are made on the basis of prices in 1977 taking the increase of traffic demand into consideration. The currency is shown in pesos, as is the capital cost, with the rate of exchange assumed at 23 pesos equalling US$1 and ¥250 equalling US$1.

At the suggestion of the Mexican side, for calculating personnel expense, per capita wages are assumed to be uniform at 150,480 pesos per year. The general management expense for material items is assumed to be 10% of other material expenses and the general management expense for personnel items is assumed to be 35% of other personnel expenses. However, general management expense calculated on the basis of figures of 20% and 50% personnel expense are also studied, as requested by Mexican side. If the general management expense is either 20% or 50% of the other personnel expenses, the difference will amount to about 5% of the total operating expense when compared with the general management expense calculated at 35% of other personnel expenses. Thus, the affect on the profit and loss and cash flow projections is rather small.

Table III-12-5 Yearly Average Operating Expenses

(In millions of pesos)

		1982-1984	1985-1989	1990-1994	1995-1996
Material expense		373 319	483 412	537 467	606 518
Personnel expense		365 349	420 391	427 395	450 414
Total	Alternative-A Alternative-B	738 668	903 803	964 862	1,056 932

For each item; Upper line = Alternative-A, Lower line = Alternative-B

12-4. Profit and Loss, Cash Flow Projections

Several cases can be considered for estimating profit and loss and cash flow projections. The most standard case, which is considered to be the most appropriate, has been prepared as the "Base Case" (Appendix Table III-12-1)

12-4-1 Base Case (Case-1)

(1) Premises

Initial capital cost (including interest during the construction period): Alternative-B = 20.7 billion pesos (US$902 million)

Additional capital cost : Alternative-B = 5.2 billion pesos (US $224 million)

Fare: 4 pesos (uniform fare throughout 15-year term)

Alternative-B is adopted with regard to operating expense. (Table III-12-5) The general management expense related to personnel expense is assumed to be 35% of the other personnel cost. Contingencies and escalation are not taken into account.

(2) The initial capital cost of the project is estimated at 20.7 million pesos (US$902 million) which is the sum of direct capital costs of 18.3 billion pesos (US$796 million) and the interest of 2.4 billion pesos during the construction period. This amount shall be paid evenly during the 3-year period for construction (from 1979 to 1981).

The financing of the initial capital cost shall be made only through borrowings as described in 12-2 "Financing Plan". Export credits in approximately equal amounts shall be obtained every year from 1979 to 1981. Repayment starts six months after the opening of business operations and is to be made in 20 equal semiannual installments. As for yen-based railway bonds, a sum corresponding to US$50 million is assumed to be issued in the Tokyo market in 1979 and then again in 1981 in order to spread the impact of Mexican fund raising on the market. Redemption of each of these bonds is to be made in 5-year installments after a 5-year grace period. The syndicated loan is to cover the balance required after obtaining the export credits and yen-bonds for each year during the construction period. Additional capital costs after the commencement of business operations are assumed to be furnished out of the general cash flow.

When cash deficits arise after the commencement of business operations, the amount of the shortfall is to be supplied by non-interest bearing funds from the Mexican Government or from other public entities. (An explanation about interest bearing funds is given later.)

(3) In terms of profit and loss, periodical profit is expected from the third year (1984) on after commencing business operations because the term of depreciation is relatively long and consequently the affect of depreciation on the profit and loss statement is relatively slight.

As can be seen from Table III-12-6, the net profit ratio gradually increases after the commencement of business operations to about 60% in 1996. The average of the ratio through the 15-year term will be 42%.

Table III-12-6 Financial Indexes for the Base Case

Year	Net Profit / Operating Revenue	Current Expense before Interest / Operating Revenue	Operating Expense / Operating Revenue	Personnel Expense / Operating Expense
1982	-39%	69%	28%	52%
1983	-13	59	24	52
1984	9	51	21	52
1985	24	50	22	49
1986	33	49	21	49
1987	42	47	20	49
1988	47	46	19	49
1989	51	45	19	49
1990	53	45	19	46
1991	55	44	19	46
1992	57	43	18	46
1993	58	42	18	46
1994	59	41	17	46
1995	59	41	18	44
1996	60	40	18	44
	42	46	20	48

(4) Cash flow deficits, however, are projected for the first five years of business operations and non-interest bearing Government assistance amounting to a total of 10.7 billion pesos will be required. If these assistance funds are to be repaid out of cash surpluses projected to arise from the sixth year and afterwards, repayment will be completed in the eleventh year (1992) after commencement of business operation, and the surplus funds projected to arise thereafter will be accumulated as cash in hand and should amount to 17 billion pesos by the end of 1996.

The operating profit rate of this project as against the initial investment under the "Base Case" consequently should be 10.2% (on a 15-year DCF basis).

12-4-2. Other Cases

Profit and loss and cash flow projections for cases, where the initial capital cost, fares, etc., are subject to change, are indicated in Appendix Table III-12-2 through III-12-4, and the comparison of major items in each case is given in Table III-12-7.

(Case-2)

This case adopts Alternative-A for initial capital cost (25. 0 billion pesos), for additional capital cost (7. 2 billion pesos), and also for operating expense. Other conditions are assumed to be completely the same as the base case.

In this case, the change in the profit and loss calculation to black figures will be delayed one year as compared with Case-1, that is until the fourth year (1985). Further, the financial assistance from the Government, etc. to supplement cash flow shortages after commencement of business is expected to be extended by one year to 6 years and the total of this assistance will reach 16. 5 billion pesos. The times at which the government assistance can be repaid out of surplus funds in this Case-2 will be delayed by two years (1994) as compared with Case-1, and the cash in hand accumulated by the end of 1996 will be reduced to 7. 7 billion pesos, which is one-half or less the funds accumulated under Case-1 (Appendix Table III-12-2).

(Case-3)

Alternative-C takes a different approach to initial capital costs by excluding the construction cost of grade separations. This approach assumes that a part of the civil engineering works of this project will be paid by government public investment. This approach is based on the rational that part of the grade separation construction basically should be borne by public investment and should not be borne solely by the railway project, meaning railway fares.

Alternative-C therefore excludes 4. 6 billion pesos for grade separation from Alternative-B. Thus, in this case, the initial capital cost (including interest during construction period) will become 16. 1 billion pesos.

According to the results of the calculation, even if the fare is assumed to be 3 pesos, the delay in the project showing a profit will be only one year (1985) as compared with Case-1. The required period of governmental assistance is 6 years and the cash accumulated in hand by the end of 1996 will be 7. 4 billion pesos which is approximately the same as in Case-2. However, the required amount of governmental assistance will be reduced to 9. 4 billion pesos, which is a substantial reduction compared with Case-1 and Case-2.

Therefore, when adopting Alternative-C and setting the fare at 3 pesos, this project is considered to be fully feasible (Appendix Table III-12-3). It becomes possible to operate the railway with a relatively light burden on users from the initial stage of operation by adopting the policy that the Government takes over part of the construction cost as a public undertaking and/or that the Government provides subsidies to this enterprise as stated in the "Financing Plan" of section 12-2.

(Case-4)

In Cases 1 to 3, cash flow deficits arising after commencing operations were assumed to be supplemented by the Government or other public entities with non-interest bearing funds. However, the other cases to be considered include, as stated in the "Financing Plan" of section 12-2, interest bearing private funds for additional medium and long term loans or a combination of Government funds and private funds.

It is assumed in this Case-4 that the cash flow shortage after commencing operations will be supplemented with interest bearing funds of 8.75% p.a. (Appendix Table III-12-4).

In this case, the financing cost will increase remarkably (an increase of 11.4 billion pesos as compared with the Case-1), resulting in pressure on the profit and loss statement lowering the rate of the annual net profit throughout the 15-year term to 24% and delaying the timing of the change-over to profitable operations to the fourth year (1985). Further, the additional loan will increase to 14.5 billion pesos as a result of interest being compounded into the interest-bearing loan and consequently the period required for repayment will be prolonged causing pressure on cash flow. However, repayment will be completed in the 14th-year (1995) which still makes the project feasible. The cash-in-hand accumulated in 1996 for this Case-4 will be 5.6 billion pesos; this is one third of the amount in case of Case-1 and is 40% less than Case-2. The amount of the necessary additional loan will increase by 3.8 billion pesos to 14.5 billion pesos when compared with Case-1, but is 2.0 billion less when compared with Case-2.

The interest in this case is calculated on the assumption that the interest rate will be 8.75% p.a. If the funds can be obtained from a source, such as the Government, offering lower interest rates, or if the Government could provide subsidies to assist payment of interest expense, the financial burden will be greatly relieved.

(Case-5)

Up to this point, the capital cost and operating expense for each year have been calculated on prices as of 1977 and escalation caused by currency-value fluctuations has not been taken into account. In this Case-5, however, the effects of cost increases caused by inflation on the profit and loss and cash flow projections are studied, and trial calculations are made to try to determine the fare hikes that will be required to cope with the cost increase.

If an inflation rate of 10% per year in Case-1 is assumed from the starting point of 1979 for the capital cost (including additional capital cost) and operating expense, the initial capital cost will increase to 22. 8 billion pesos (a 10% increase over Case-1), and the total operating expense will amount to the colossal sum of 35. 7 billion pesos (a 290% increase over Case-1).

In order to still be able to repay government assistance and achieve a cash flow balance in the fifteenth year after the commencement of operation, the following fare hikes would be necessary;

4 pesos/person for 1982-1986 (5 years after operation)

5 pesos/person for 1987-1991 (the next 5 years)

6 pesos/person for 1991-1996 (5 succeeding years)

The cost index for increases of 10%/year will reach 380 in the 15th year as against 100 at the commencement of operations. However, the fare index would remain at 150 in the 15th year (6 pesos/person) as against 100 (4 pesos/person) for the first year (1982).

(Case-6)

Here the calculation was performed assuming the fare (referred to in Case 1) will be 5 pesos. This results in the balance of operational revenues and expenditures turning into the black in the second year from the inauguration of the project and also in a far smaller shortage in funds (6, 700 million pesos) than would result in other Cases. If this shortage is filled by a loan from outside sources, then the liquidation of the loan will be completed in the 8th year (1989).

This means that if the fare is set at 5 pesos, the financial burden of this enterprise will be greatly reduced in terms of operational revenues, expenditures, and cash flow, thereby permitting earlier financial independence of the enterprise.

Table III-12-7 Comparison of Profit and Loss, Cash Flow Projections

	Case-1 (Base Case)	Case-2	Case-3	Case-4	Case-5	Case-6
Initial capital cost	20,741 MP (Alter-native-B)	25,023 MP (Alter-native-A)	16,092 MP (Alter-native-C)	20,741MP (Alter-native-B)	22,780MP	20,741MP (Alter-native-B)
Fare	4 pesos	4 pesos	3 pesos	4 pesos	1982-86 4 pesos 1987-91 5 pesos 1992-96 6 pesos	5 pesos
General management expenses as percent of other personnel exp.	35%	35%	35%	35%	35%	35%
Escalation	None	None	None	None	10% p.a. for capital cost and operating expense (from '79)	None
Add loan/Assistance interest	0%	0%	0%	8.75%p.a.	0%	0%
I) Profit and Loss						
1) Ave. yearly net profit (thru. terms)	1765 MP	1284 MP	954 MP	1008 MP	1122 MP	2803 MP
2) Ave. net pro./Ave. ope. rev.	42%	31%	31%	24%	21%	54%
3) Year profit first expected (year from inauguration)	1984 (3rd Yr.)	1985 (4th Yr.)	1985 (4th Yr.)	1985 (4th Yr.)	1985 (4th Yr.)	1983 (2nd Yr.)
4) Operating Ratio (thru. terms)	46%	55%	57%	46%	69%	37%
II) Cash Flow						
1) Years Asst/Add loan required	5 Yr.	6 Yr.	6 Yr.	6 Yr.	6 Yr.	5 Yr.
2) Total Asst/Add loan	10.7 BP	16.5 BP	9.4 BP	14.5 BP	17.2 BP	6.7 BP
3) Cash flow bal. first attained (=Year Asst/Add loan fully repaid)	1992	1994	1994	1995	1996	1989
4) Accumulated cash bal. at 1996 year end	17.0 BP	7.7 BP	7.4 BP	5.6 BP	1.0 BP	32.5 BP
Appendix Table	III-12-1	III-12-2	III-12-3	III-12-4		III-12-5

Note: MP = million pesos, BP = billion pesos, rev. = Revenue, thru = through,
Ave. = average, pro. = profit, ope. = Operating, exp. = Expense

13. Economic Evaluation of the Project

13-1 Method for Economic Evaluation

In order to make an economic evaluation of this Project, first the economic cost of the project and the economic benefit to the national economy resulting from the project both were computed. Then the internal rate of return (I. R. R.) was calculated based on the results of those computations.

13-2 Costs

Costs have been calculated based on the planned expenditures for each year pursuant to the total funds required for the project (Alternative-B), excluding the cost of interest, taxes and dues.

The various economic costs are divided, for simplification, into capital costs (such as for fixed facilities and vehicles), and costs for maintenance, control and operation, adopting the projected figures set forth in the project program, without regard for shadow prices.

The Project will restore and utilize once abandoned roadbeds for rights of way, which will not involve purchases of land. Accordingly the cost of land purchase is not included in the above-mentioned total amount of required project funds. In this economic evaluation, however, viewing that such cost (for Rights of Way) should be included in the total economic cost even though the road-beds will only need to be restored. These costs given as below are assumed to be expensed in the first year of the project (1979).

	(total length)		(average width)		
Tracks	77 km	x	15 m	=	$1,155 \times 10^3$ m^2
Stations					122
Car depots					750
					$2,027 \times 10^3$ m^2

$(2,027 \times 10^3\ m^2) \times 500^*$ pesos = 1,013.5 million pesos.

Note: (*) Land price is estimated to be 900 pesos/m^2 in the center of the City and 250 pesos/m^2 toward the ends of the railroad in question, but here it is assumed that 500 pesos/m^2 is invariably the average land price.

The book values of vehicles, station buildings etc., (10,521 million pesos) at the end of the last year of the project's life (1996) assumed for this calculation are to be deducted from the cost column in 1997 as the residual values after the lapse of the life of the project.

18,316 million pesos	......	Initial expenses (excluding interest incurred during construction period)
+ 5,148	......	Additional investment
+ 1,014	......	Right of Way
-13,957	......	Depreciated value until the end of 1996
10,521 million pesos	......	Residual value

13-3 Benefit

The following elements are generally considered to be the benefit of railroad transport projects.

(i) Reduction of transport cost (operational cost + capital cost) for users of new facilities.

(ii) Reduction of transport cost for the continued users of existing facilities similar to (i) above, due to the easing of traffic congestion.

(iii) Savings in transport time of passengers or commodities.

(iv) Stimulation of economic development in the project area or its vicinity.

(v) Reduction in accidents or damages derived from accidents.

(vi) Increased comfort and convenience to spatial shift of passengers.

(vii) Other economic benefit, such as the reduction of exhaust gas.

Most of these benefits are hard to quantify, and in addition the basic data suitable for analysis is quite limited. For this analysis, therefore, the study and review is to be centered about elements (i) and (iii) above.

13-3-1 Future Traffic Volume

The estimated future traffic volume serving as the base for computing the economic benefit has been studied and reviewed separately. Total passenger transport distances (persons x km) broken down by years are computed based on the estimated value of the number of passengers and are given in the Attached Table III-13-1.

13-3-2 Traffic Costs

The traffic costs for the purpose of this analysis are (i) travelling cost, (ii) fixed cost, and (iii) time cost, excluding costs for accidents, as these include many intangible factors and are difficult to quantity.

Partly because of the limited time available for this study, most of basic data cited below has been taken from the data and information obtained from the Mexican authorities.

A. Travelling Cost

Usually the travelling cost for vehicles such as buses and passenger cars (conventional types of transportation) is considered to consist of the cost of fuel, oil and tires and of maintenance and repair as well as a part of the capital cost. To simplify the analysis to an extent not injuring the purpose of this clause, the computation has been made by the method described below.

In calculating the cost for this clause, the part corresponding to the capital cost was excluded from the above-mentioned usual cost elements, and the fuel cost was used as the basic element, presuming that all the remaining cost elements amount to 50% of the cost of fuel.

The calculation resulted in the following:

(in pesos/persons x km)

	Bus	Passenger car
Fuel	0.008	0.287
Other (=Fuel x 50%)	0.004	0.144
Total travelling cost	0.012	0.431

Note: Basis for Calculation

	Bus	Passenger car
Average number of passengers (including driver)	45 persons/car	1.5 persons/car
Distance covered per liter of fuel	3 km	6.5 km
Fuel	Gasoline 20% Diesel oil 80%	Gasoline
Fuel cost	Gasoline: 2.8 pesos/liter Diesel oil: 0.65 pesos/liter	

(All these figures are based on the survey and review made by the Mexican authorities.)

B. Fixed Cost

In order to reach a level of accuracy, similar to the calculation of travelling cost, the study should have been made by dividing the fixed cost into the remainder of capital cost, personnel cost, indirect cost etc., but for present purposes a simplified method was adopted whereby the purchase price of vehicles (with tax deducted) is counted as fixed cost by counting the capital cost (excluded in A above) as a fixed cost and excluding personnel cost from consideration.

The prices of vehicles assumed for purpose of analysis are given below.

	Bus	Passenger car
Price (tax deducted)*	890, 330 pesos	101, 568 pesos
Service life**	7. 5 years	9 years
Fixed cost p. a. (per vehicle/year)	118, 711 pesos	11, 285 pesos

Notes: (*) Based on the import price (before tax) in Mexico:

Bus: US$ 38, 710

Passenger car: US$ 4, 416

(**) Service life was supposed to be 150% of the legal service life for each bus and passenger car based on the Detailed Enforcement Regulations of the Japanese Tax Law.

C. Time Cost

A simplified method for calculating the time cost has been used whereby the time values are calculated for all drivers and passengers of buses and of passenger cars including personnel costs (for bus driver etc.) excluded from the fixed cost set forth in B above.

The data used by the Mexican authorities was used as the basis for calculation. It was felt, however, that the application of the uniform minimum wage of 106 pesos/day to all of the passengers needed further study in view of the large number of passengers to be multiplied by this wage. Accordingly the following method was adopted.

It may be unrealistic to assume that all passengers have the uniform time value of 106 pesos/day. Therefore it has been assumed that classification can be made according to the circumstances of passengers, by making distinctions for (a) working hours, (b) commutation, and (c) leisure time, and giving each a different time value. The time value of a passenger who is accustomed to using a passenger car is normally of a higher level than that of a passenger who used buses and thus the time value for the former is evaluated to be twice as high as for the latter.

The composition according to purposes of use, and the time values according to types of vehicles are shown below.

	Purpose of use	Composition by purposes	Time value	
			Bus	Passenger car
(a)	Working hours	25%	13.25 pesos/h	26.5 pesos/h
(b)	Commutation	50%	6.625 (= (a) x 1/2)	13.25
(c)	Leisure time	25%	2.65 (= (a) x 1/5)	5.30

The time values of drivers of both types of vehicles are supposed to be same as for their respective passengers. (It can be assumed that the "Time value of owner driver" = 2 x "Time value of bus passenger" and that, speaking of employed chauffeurs, the fellow passenger (= employer) can be considered to have a higher time value than supposed above. The above-mentioned supposition applies when both cases are averaged, but, on the other hand, the time values for bus drivers will be approximated on an average basis with that of their passengers because of the large number of bus passengers, 44 persons/vehicle in average.)

D. Traffic Cost

The traffic costs by types of vehicles for items A thru C above are as follows:

	Bus	Passenger car
Travelling cost (pesos/person x km)	0.012	0.431
Fixed cost (pesos/vehicle x year)	118,711	11,285
Time cost (pesos/person x h)	7.288	14.575

To convert the time cost to that of a basis of "per travelling distance (person x km)", it has been supposed that the average speed is 15 km/h for buses, and 30 km/h for passenger cars (based on the figures used by Mexican authorities), which lead to the following result.

	Bus	Passenger car
Time cost (pesos/person x h)	7.288	14.575
" (pesos/person x km)	0.486	0.486

Thus, by comparing the above costs with the cost of railroad services for the same unit (calculated on the supposition of an average speed of 53 km/h), it is possible to measure the effect of reduction in time cost resulting from railroad construction.

	Bus	Passenger car
On-road time cost (pesos/person x km)	0.486	0.486
On-railroad " (")	0.138	0.275
Reduction in time cost (pesos/person x km)	0.348	0.211

Similarly, supposing that both buses and passenger cars run 8 hours per day, for the fixed cost the purchase prices of vehicles/service life have been converted to those per number of passengers x km, on the supposition that the marginal transport is shifted to the railroad.

	Bus	Passenger car
(a) Fixed cost (pesos/vehicle x year)	118,711	11,285
(b) Passenger transport distance (person x km/vehicle x year)	15km/h x 8h/d x 365d x 45per.	30km/h x 8h/d x 365d x 1.5per.
(a) ÷ (b) Fixed cost (pesos/per. x km)	0.060	0.086

13-3-3 Economic Benefits

From the results obtained in the foregoing clause, the economic benefits resulting from the railroad construction can be calculated in term of the effect of the reduction in traffic cost broken down according to types of vehicles as shown below.

	Bus	Passenger car
A. Reduction in travelling cost (pesos/person x km)	0.012	0.431
B. Reduction in time cost (pesos/person x km)	0.348	0.211
C. Reduction in fixed cost (pesos/person x km)	0.060	0.086
Total (pesos/person x km)	0.420	0.728

It must be added here that, as mentioned above, the benefits for which the quantification has been attempted are only part of the total expected from the completion of this Project, and that it would be hasty and dangerous to judge the benefits of the Project merely from the above-mentioned effects.

13-4 Internal Rate of Return

The internal rate of return (IRR) obtained from Clauses I thru III is as follows:

IRR = 13.2 %

From the favorable result obtained in Clause III. 3 above, and also considering that the analysis of the benefits has been made on a conservative basis, this result shows a very high degree of safety and indicates a sufficiently satisfactory value.

Thus, it also can be concluded that this Project is feasible in economic terms.

We have so far proceeded with analytical work chiefly centered about points (i) and (iii) from the economic benefits listed in III. (i) thru (vii) which will accrue to the national economy through the implementation of this Project. The remaining benefit items not discussed here are not of lesser importance and can contribute to bringing about greater benefits than those studied above.

We have limited our evaluation only to economic benefits. The benefits to be obtained from implementing this Project, however, will not be limited only to economic aspects, but will also include substantial social benefits such as reduction of exhaust gas or restriction of its increase, reduction or prevention of noise pollution, promotion of inter-community communications, change in social structure, balanced economic development among regions, etc. These aspects should be fully appreciated in the comprehensive evaluation of the Project.

Table III-13-1 Total Passenger Transport Distance by Years

	Estimate of Transport Volume by Suburban Railway		Estimate of transport volume by types of vehicles in case of no railway service	
Year	Total number of passengers (million persons/year)	Total transport distance (million km-per. /year)	Bus (70%)* (million km-per. /year)	Passenger car (30%)* (million
1982	590	5,336	3,735	1,601
83	701	6,363	4,454	1,909
84	812	7,930	5,551	2,379
85	923	8,417	5,892	2,525
86	959	8,774	6,142	2,632
87	995	9,131	6,392	2,739
88	1,031	9,488	6,642	2,846
89	1,067	9,845	6,892	2,953
90	1,105	10,204	7,143	3,061
91	1,141	10,556	7,389	3,167
92	1,177	10,908	7,636	3,272
93	1,213	11,260	7,882	3,378
94	1,249	11,612	8,128	3,484
95	1,287	11,964	8,375	3,589
96	1,323	12,316	8,621	3,695

Note: * It is assumed that out of the total transport distance of the Suburban Railway, 70% will be traffic shifted from buses, and 30% will be traffic shifted from passenger cars.

Table III-13-2 Internal Rate of Return (IRR)

	Costs				Benefits					Benefits −Costs	D.F. 13% p.a.	Present Value	D.F. 14% p.a.	Present Value
	Initial Capital Cost	Additional Investment	Operation and Maintenance	Total	Total transport distance (million km-per. /year)	Travelling cost reduction	Time cost reduction	Fixed cost reduction	Total					
	million pesos	million pesos	million pesos	million pesos		million pesos	million pesos	million pesos		million pesos				
1979	*7,117			7,117						Δ7,117	1.0000	Δ7,117	1.0000	Δ7,117
1980	6,104			6,104						Δ6,104	.8850	Δ5,402	.8772	Δ5,354
1	6,108			6,108						Δ6,108	.7831	Δ4,783	.7695	Δ4,700
2		505	665	1,170	5,336	735	1,638	362	2,735	1,565	.6931	1,085	.6750	1,056
3		505	667	1,172	6,363	876	1,953	431	3,260	2,088	.6133	1,281	.5921	1,236
4		505	670	1,175	7,930	1,092	2,434	538	4,064	2,889	.5428	1,568	.5194	1,501
5		803	803	1,606	8.417	1,159	2,583	571	4,313	2,707	.4803	1,300	.4556	1,233
6		231	804	1,035	8,774	1,208	2,693	595	4,496	3,461	.4251	1,471	.3996	1,383
7		231	804	1,035	9,131	1,257	2,802	620	4,679	3,644	.3762	1,371	.3506	1,278
8		231	804	1,035	9,488	1,346	2,912	644	4,902	3,867	.3329	1,287	.3075	1,189
9		231	804	1,035	9,845	1,356	3,022	668	5,046	4,011	.2946	1,182	.2697	1,082
1990		601	860	1,461	10,204	1,405	3,132	692	5,229	3,768	.2607	982	.2366	892
1		195	861	1,056	10,556	1,454	3,240	715	5,409	4,353	.2307	1,004	.2076	904
2		195	862	1,057	10,908	1,502	3,348	739	5,589	4,532	.2042	925	.1821	825
3		195	864	1,059	11,260	1,551	3,456	764	5,771	4,712	.1807	851	.1597	753
4		195	865	1,060	11,612	1,599	3,564	788	5,951	4,891	.1599	782	.1401	685
5		331	932	1,263	11,964	1,647	3,672	812	6,131	4,868	.1415	689	.1229	598
6		195	933	1,128	12,316	1,696	3,780	835	6,311	5,183	.1252	649	.1078	559
7	** Δ10,521			Δ10,521						10,521	.1108	1,166	.0946	995
												291		Δ1,002

$$IRR = 13 + \frac{291}{291 + 1,022} = 13.2\%$$

Notes: * Includes 1,014 million pesos for Right of Way.

** Deduction of residual value.

14. Education and Training Plan

14-1 Fundamental Policy for Education and Training

The education and training of personnel is the key to the progress and development of a railway. It is necessary to conduct education and training to the management staff, foremen and general personnel through given system and methods on a planned and organized basis. This also forms a part of personnel management for improving the ability and uplifting the will of personnel to perform their own work. It is intended to make personnel, the foundation of railway operation, understand the importance of railway transportation services and their responsibility as railway personnel and make them master the knowledge and skill to meet technical improvement and the introduction and development of new technology.

This Suburban Railway particularly intends to introduce new technology widely into each department and perform mass and high-density transportation. To accomplish smooth operation and management of this railway, it is important to give personnel the education and training centered around technology on a planned basis.

14-2 Required Education and Training

It is necessary to perform education and training generally in correspondence to the following cases:

- (i) Employment of new personnel
- (ii) Scheduled promotion in ranking or transfer of personnel
- (iii) Any change in job specifications
- (iv) Improvement of equipment, vehicles, facilities, etc.
- (v) Change in operating methods
- (vi) Introduction of new technology
- (vii) Any establishment, alteration or abolition of regulations
- (viii) Particular supplementary study needed for knowledge or skill related to jobs

Below is given the description on the principal education courses.

14-2-1 Education of newly employed personnel

Newly employed personnel are to be given fundamental education necessary to make them understand the mission of railway services and their respective duties so that they may engage themselves in their jobs with good confidence.

14-2-2 Management staff education

The management staff must have distinct ability for a planned job promotion and leadership ability over the personnel in their charge. For this purpose, it is necessary to give education on management control and modernization, etc., always in advance and with rich content.

14-2-3 Foreman education

The role of foreman as center of field activities is of great importance for smooth performance of work. In this meaning, sufficient education is to be given on the specialized engineering, leadership skill and safety so that foremen can excercise leadership with confidence in technical aspects.

14-3 Education and Training Plan

This Suburban Railway will have many new technologies introduced into its various fields, and for smooth utilization of those facilities, it is necessary to enrich the engineering ability on each of the levels of management staff, foremen and general personnel. If excellent leaders are brought up in success by enriching the education and training particularly on the levels of management staff and foremen, it will be possible to bring up ten-odd times as many excellent general personnel centered about those leaders.

14-3-1 Education and Training Methods

There will be adopted an education propagation system, that is, a system in which, first, management staff and foremen (i.e. leaders) are brought up by departments or sections, and then these leaders bring up general personnel.

(i) Management Staff Education

Education is to be conducted to those, selected from the persons preferably experienced in railway services, who have the specialized knowledge of the university graduate level, sufficient ability to prepare educational documents and the leadership ability for education.

The important point for efficient education is to secure those persons who have experience particularly in railway service jobs. It is needed to heighten the educational efficiency through classroom on-paper education, training at manufacturers and training in the Country cooperating in this Project.

(ii) Foremen Education

Education is to be conducted to those, selected from the persons preferably experienced in railway services, who have the specialized knowledge of the high-school graduate level and have the leadership ability for education of general personnel.

This is the education to be given to those foremen who will become the nuclei of the persons to receive general education and training, by sections - train crew, vehicle repairs, track maintenance, electric power, signals, telecommunications, etc.

This includes theoretical on-paper education, training at equipment manufacturers or by lecturers from those manufacturers, and in addition, practical education with simulators or equipment under manufacture or construction. If needed, training in the Country cooperating in this Project will be added.

It will be very efficient if fundamental training can be conducted with the cooperation of some existing railways.

(iii) General Personnel Education and Training

The education and training to general personnel is to be conducted by the above-mentioned leaders, with an increased educational efficiency through practical training in addition to classroom on-paper education.

To enrich the engineering knowledge and skill on the actual service training of train operation, and facilities inspection and repair, the leaders are required to master new technology on actual equipment and get accustomed to the equipment and facilities.

14-3-2 Substance of Education and Training

The leaders such as management staff and foremen are to be given the education with the following substance.

(i) Theories by specialized fields

(ii) Control and management services by specialized fields

(iii) Inspection techniques, repairing techniques by specialized fields

(iv) Safety management and countermeasures against accidents

Particularly the foremen need to get accustomed to the following items respectively by their specialized fields:

(1) Operations (vehicles, signal security, driving technique, etc.)

(2) Tracks (inspection system, maintenance equipment, etc.)

(3) Substations (AC feeder facilities, remote control system, etc.)

(4) Vehicle power supply line (types of suspension, vehicle power supply line, accessory facilities, etc.)

(5) Signal and telecommunication (track circuits, relay circuits, ATC, etc.)

(6) Vehicle inspection and repair (vehicle structures, inspection and repairing equipment, operational process, etc.)

(7) Station facilities (automatic ticket vendor and examiner, escalators, etc.)

14-3-3 *Terms of* Education

At least four to six months will be required as terms (periods of time) of education on each level.

At least six months before the inauguration of this Suburban Railway, therefore, a model line (short track section) shall be completed as a field of practical education of the education and training program, where education should be conducted on train operation, vehicle inspection and repair, electrification, and also on inspection and maintenance of signal and telecommunication, tracks, etc.