ROUTE LOCATION PLAN
CHAPTER 3

CHAPTER 3 ROUTE LOCATION PLAN

3-1 Preconditions for Route Location

The following points were considered as preconditions for station location and route selection.

(1) The route is scheduled to connect Apaseo el Grande (starting point) and San Francisco del Rincon (termination). Stations should be located in each of the major cities existing between those two points.

(2) Through operation over the existing National Railways is not planned.

(3) Construction costs should be kept to a minimum.

Although there may be some alternative plans for route selection, only the route which best connects the station sites proposed in the following items is adopted for this study.

3-2 Station Location

3-2-1 Basic policies for station location

The following points, in addition to the route location preconditions referred to in 3-1, have been considered in selecting the station site, because the railway proposed under this project will carry interurban as well as commuting passengers.

(1) While duly considering the characteristics of an interurban railway, the station location in each existing main city should be based on the principle that each city will have one station.

(2) The station site should be selected so as to transport commuters to the residential town and the industrial complexes proposed by the State Government.

(3) Any planned large projects (such as the new airport construction plan) should be considered fully prior to selection of the station site.

(4) In siting a station, the existing city center (Centro Urbano and Sub-Centro Urbano), main facilities (bus terminal, cultural facilities, higher education facilities, and public markets), and main road should be considered. Also, the station location in the urban area should not favor one specific direction.

3-2-2 Station location

A station location plan has been developed based on preconditions and basic policy mentioned above.

A total of 14 stations are planned from Apaseo el Grande to San Francisco del Rincon (Table 3-2-1).

Incidentally, no station is proposed for the city of Cortazar for the reason stated later in the description of Villagran Station.

In the single-track section, signal stations will be provided at an interval of 6 to 8 km to ensure sufficient track capacity.

Requirements considered for siting of each station are summarized below.

Table 3-2-1 Proposed Stations

Name of Station	Location (Municipio)
Apaseo el Grande	Apaseo el Grande
A	"
Celaya	Celaya
Villagran	Villagran
B	Salamanca
Salamanca	"
C	Irapuato
Irapuato	"
Silao	Silao
D	"
E	Leon
Leon	"
F	"
Sn. Fco. del Rincon	Sn. Fco. del Rincon

Note: Indicated by each proper name is the station selected near the urban center in each existing city. Lettered stations are proposed for other related development projects (residence, industrial complexes, and the airport).

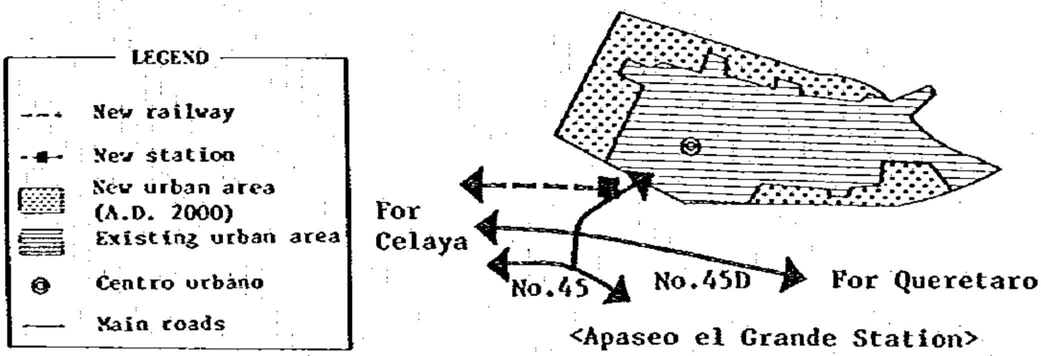
(Apaseo el Grande Station)

The following points have been considered for siting Apaseo el Grande Station.

a) As a matter of fact, this is the station at the terminating end of the new railway line proposed under this Project. However, the station should be designed for future potential extension to Queretaro, a large city neighboring the east side of Apaseo el Grande City.

b) Because the urban area is limited to a small scale, there should be relatively less necessity for siting of the station near the center of city.

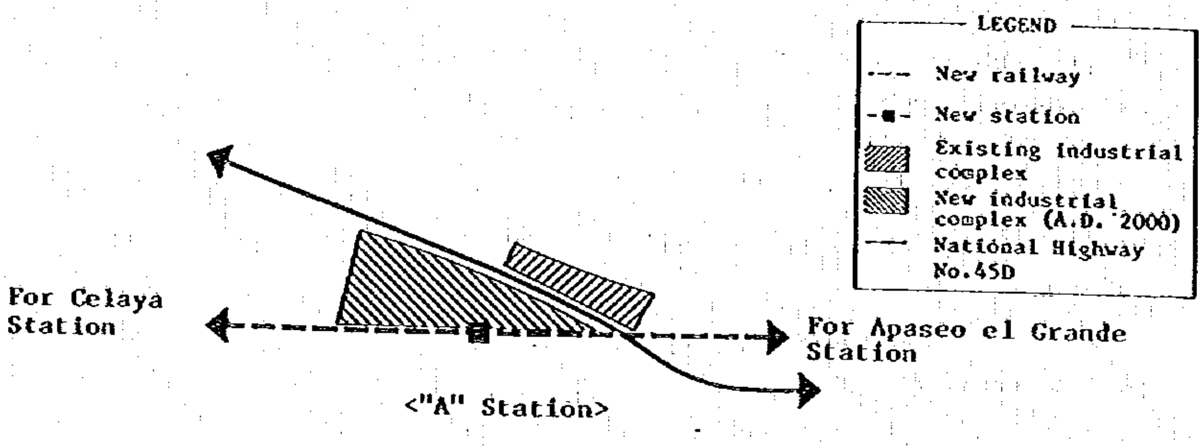
In view of these factors, the station site has been assumed near the main road at the southwest of the future urban area. The proposed site is located near National Highway No. 45, which serves as the main road in the Bajio Industrial Corridor.



<Apaseo el Grande Station>

(Station A)

Station A should be established mainly for commuting and business connection to and from both existing and proposed industrial complexes. The station site has been selected near the center of the industrial complex, considering the possible extension of the radius within which persons use a particular station.



(Celaya Station)

As a result of the route selection study, the route should run on elevated track above the median strip of the main road running from east to west at the city center.

Therefore, unlike the proposed stations for other cities, Celaya Station can be located near the center of the urban area.

The station is therefore to be located at a corner of the concentrated district of high-educational facilities, sports center, public parks, and other city facilities.

The following have been considered:

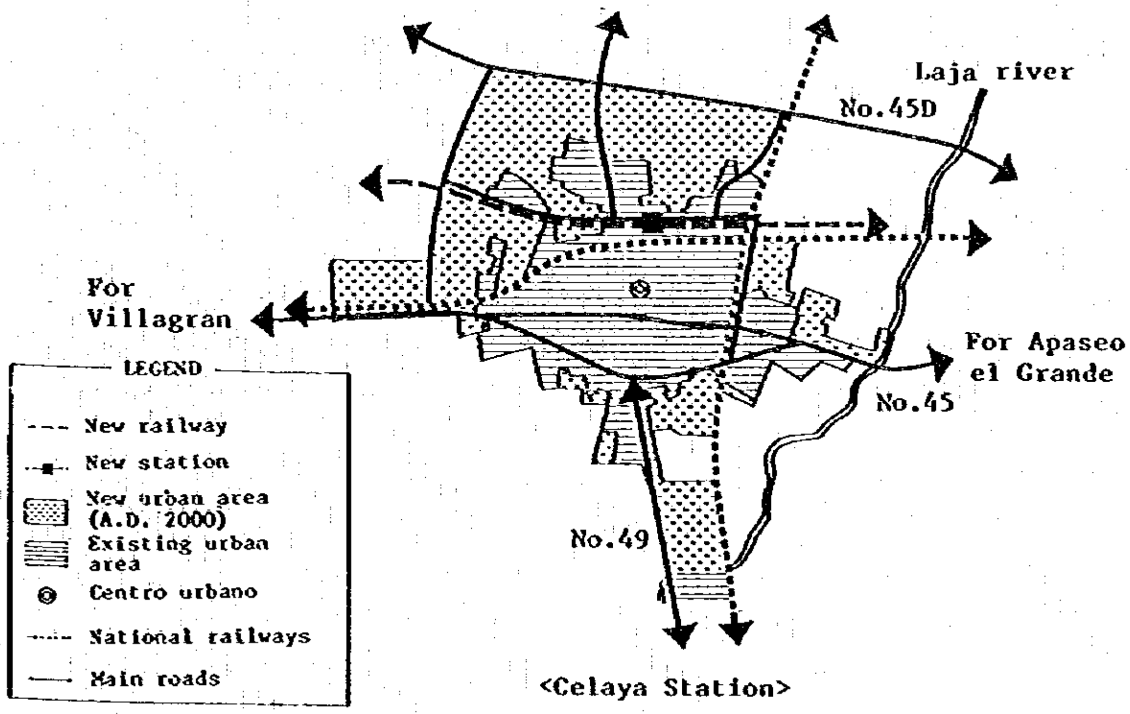
a) The station site is near the Centro (about 1,700 m).

b) The station site is near the community area of high-education facilities, sports center, and public parks.

c) The station site is geographically near the center of the urban area, at the shortest distance from most parts of the urban area.

d) The station is close to the main roads within the urban area.

e) The station is a short distance (about 400 m) from Celaya Station on the National Railways.



<Celaya Station>

(Villagran Station)

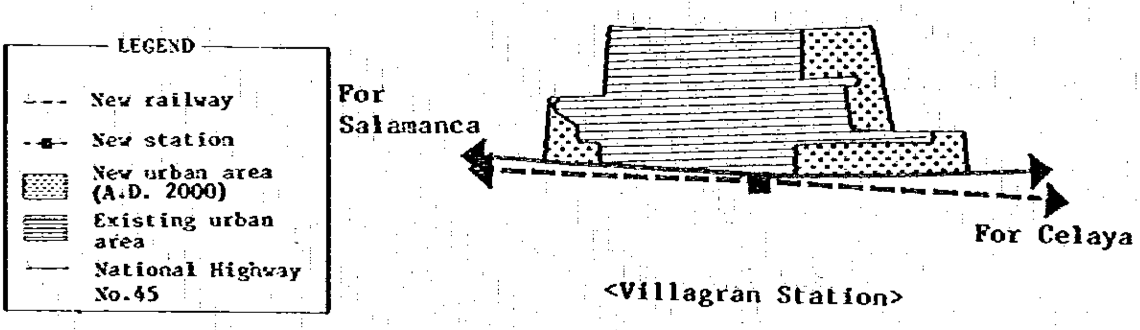
The area within which passengers would be likely to use Villagran Station covers mainly Villagran City and Cortazar City to the south. The proposed station site is near the urban area of Villagran City to conveniently interconnect with Celaya in the east and Salamanca in the west. (See footnote below.)

After study, Villagran Station has been assumed near the southern urban area in Villagran, considering the following points.

a) Because the Villagran urban area is small (nearly within walking distance), it is not necessary to locate the station in the inner urban area. Considering this point, the site has been assumed near the urban area.

b) The site has been assumed on the southern side of the urban area, considering the necessity of convenient interconnection with Cortazar City.

c) The site is proposed near National Highway No. 45, the main road in the Bajio Industrial Corridor, because this location is convenient for other transportation.



<Villagran Station>

Footnote: Because it is desirable to use the shortest route between the urban areas of Salamanca and Celaya, it has been decided that no station site be proposed in the urban area of Cortazar City.

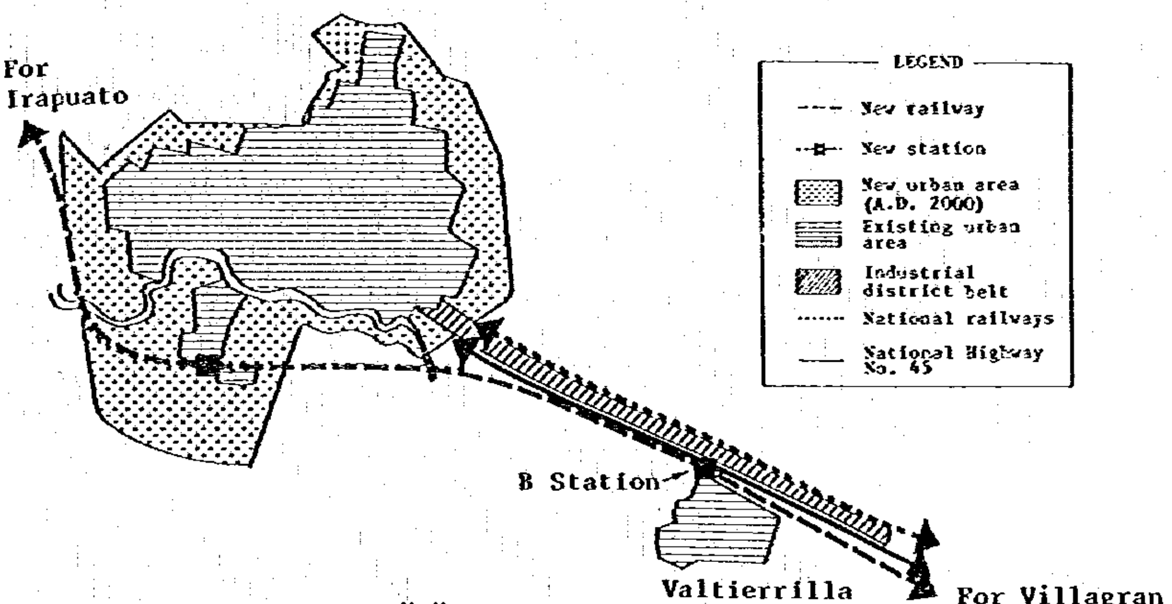
(Station B)

Station B is proposed mainly to serve the Valtierrilla area (about 10,000 population as of 1983) and the industrial district belt being developed along National Highway No. 45 and the existing railway line.

In selecting the station site, the following points have been considered.

a) Near the urban area of Valtierrilla

b) Near National Highway No. 45



<"B" Station>

(Salamanca Station)

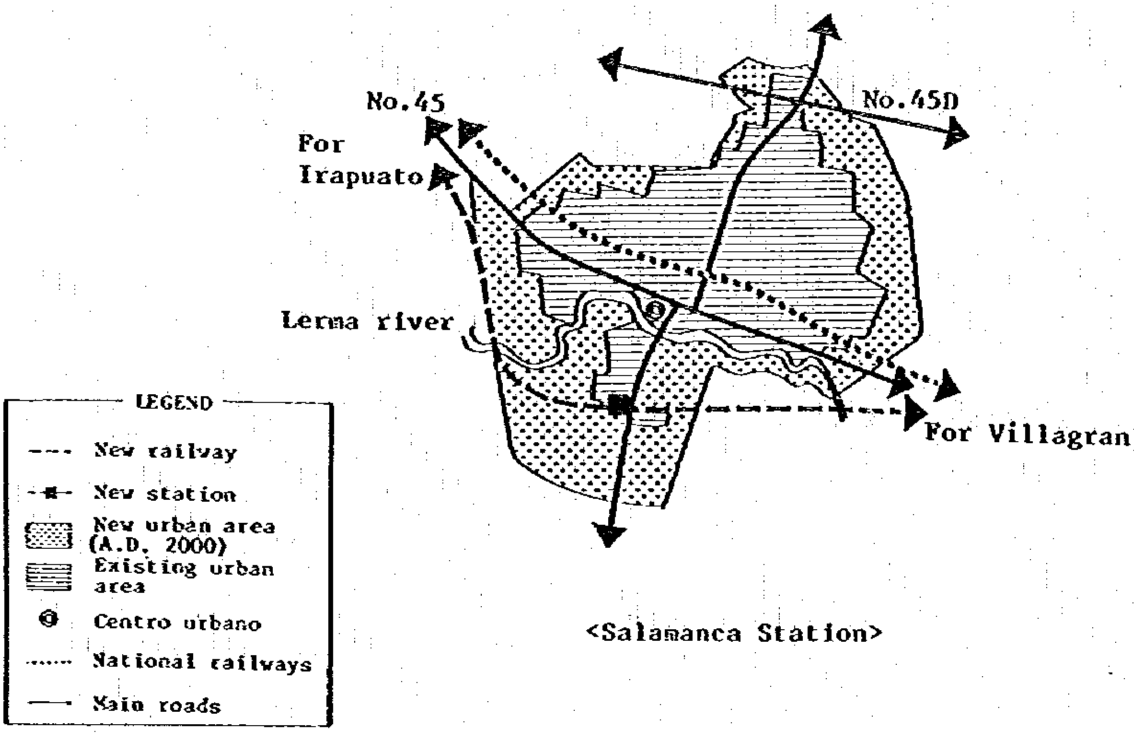
Salamanca Station is assumed at the center of the southern urban area of Salamanca City, considering the following points.

a) The existing urban city on the north side of Rio Lerma is densely populated and, furthermore, the eastern zone of the north urban area is proposed for a PEMEX plant site which will cover a wide area, therefore it is difficult to plan construction of a new railway line in those areas.

b) Nevertheless, the railway station (and railway route) can be established in the south urban area at the present time, though the southern area is now being urbanized.

c) Because the south urban center is planned as the Sub-Centro Urbano and, besides that, the interurban bus terminal is also projected in the neighborhood of the Sub-Centro Urbano, it is possible that the site can be developed as an integrated traffic center in the urban area of Salamanca by establishing the railway station there.

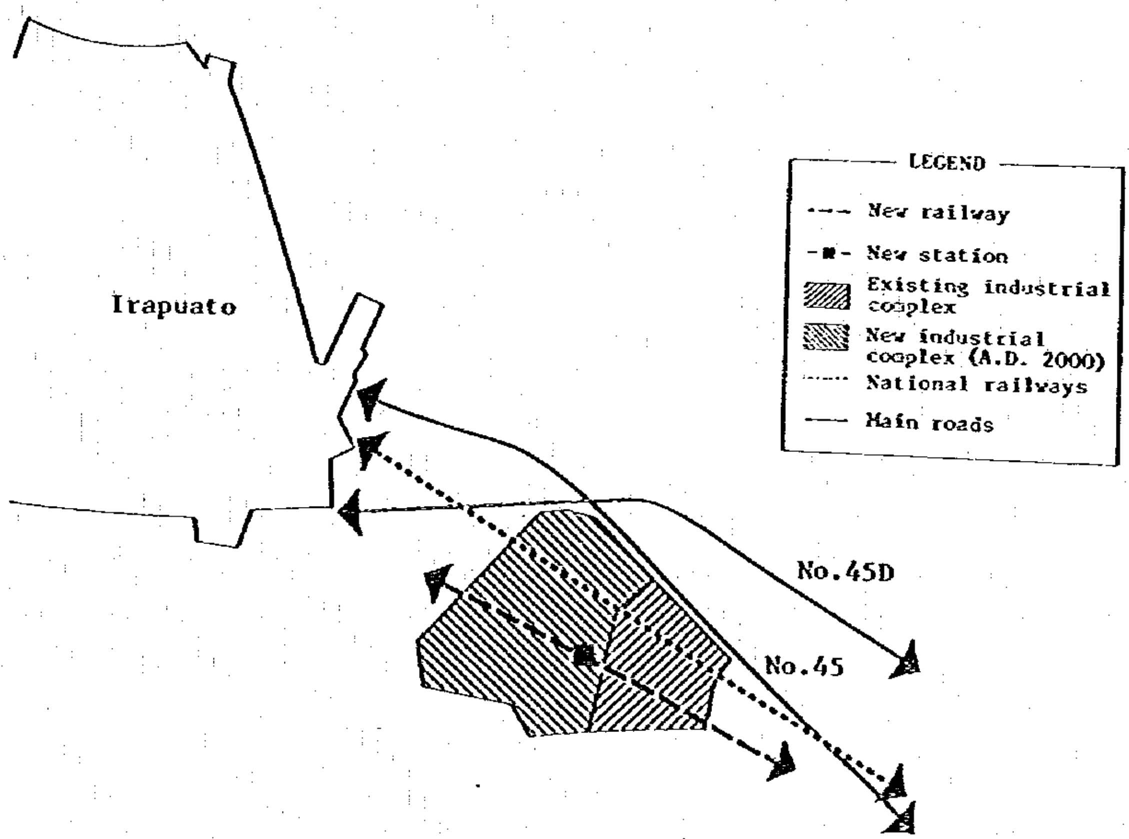
d) The site is located near the urban main road passing through the center of the urban area from north to south and has relatively good accessibility to the Centro Urbano (about 2 km in distance).



<Salamanca Station>

(Station C)

As in the case of siting Station A, Station C should be sited to provide commuting and business connections to the existing and proposed industrial complexes. The site has been selected nearly at the center of the industrial complex, considering the radius within which persons use a particular station.



<"C" Station>

(Irapuato Station)

The urban area of Irapuato is elongated from north to south. Therefore, if the project east-west extension route detours around the outskirt of the urban area, it would naturally result in increases of both travelling time and construction cost.

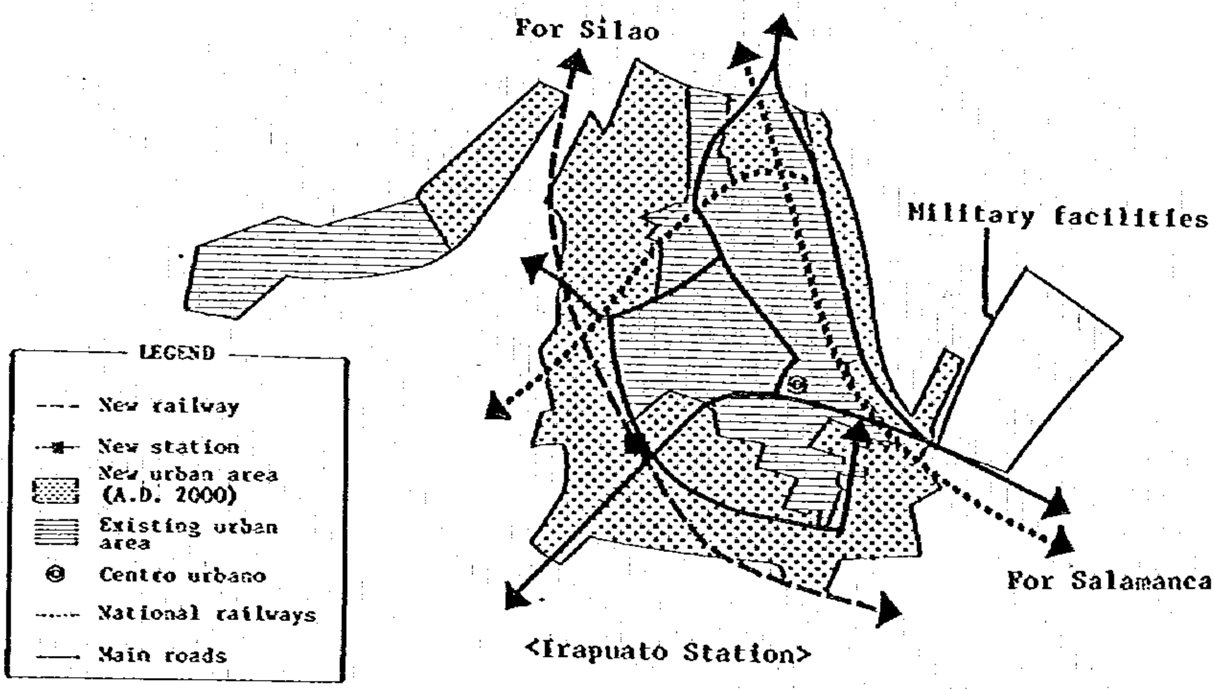
For this reason, it is inevitable that the route should pass through the urban area. The proposed site for Irapuato Station has been selected, considering this and the following points.

a) Because the populated area already exists both north and east of the city center, there is very little possibility of passing above the road as in the case of Celaya City.

b) It is difficult to locate the route across the military facilities to the northeast of the urban area.

c) Since both southern and western areas of the city area planned for urbanization around the year 2000, there is a high possibility that the railway route can be developed under the systematic plan.

d) The area near and around the proposed site for the new station in the southern urban area is planned for development of the Sub-Centro Urbano, and is also served by the main road (National Highway No. 90). Therefore, the new station can be developed as an integrated part of the whole city development scheme.



<Irapuato Station>

(Silao Station)

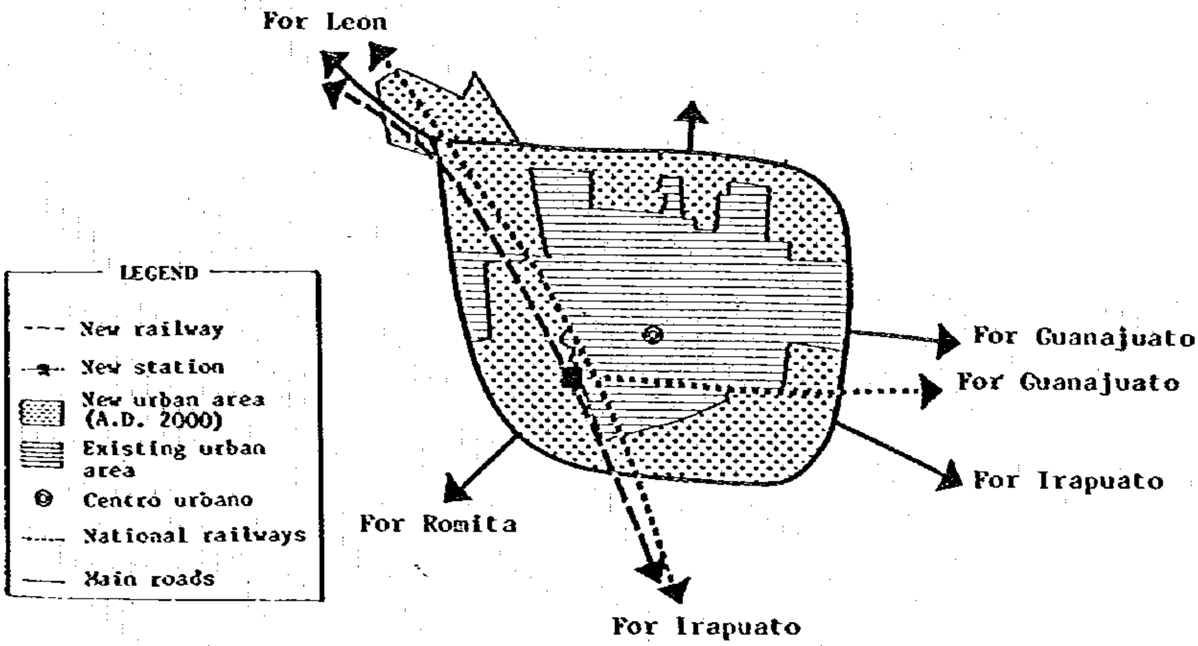
The Silao Station site is proposed near the contact point between the southwest of the existing urban area and the new development urban area, considering the future tendency toward urbanization. The matters considered for selection of the site are as follows.

a) The urban area of Silao is planned for equal extension in every direction. However, large future expansion of the area, on the southern side of the existing National Railway in particular, is envisaged by the development plan. Furthermore, at the present stage there is a large possibility that the railway construction plan can be incorporated into the urbanization plan as a whole.

b) In and near the area proposed for construction of the new station, there is a development plan for the Sub-Centro Urbano, which can be integrated with the construction plan of the new railway station.

c) The site is located near Silao Station of the National Railways (about 200 m).

d) Selecting a site on the northern side of the existing urban area would make the route longer and increase the number of separated grade crossings with National Highway No. 45 and the existing railway track line. This would result in large cost increases.



<Silao Station>

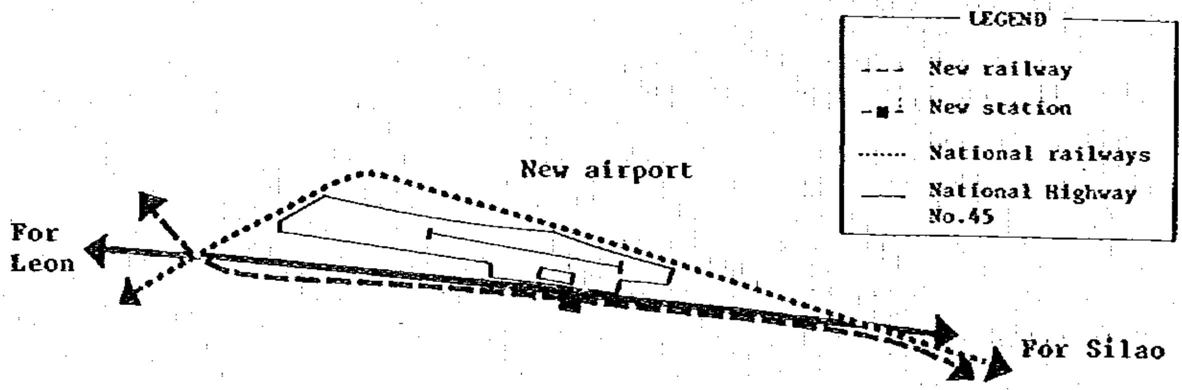
(Station D)

Station D has been assumed as the station for interconnection with the "New Airport" now being planned by the Federal Government in the west of Silao City.

The construction site for Station D has been selected on the south side of the airport after considering the following points.

a) The airport terminal building is proposed at the southern end of the new airport site.

b) National Highway No. 45 passes through the southern side of the new airport.



<"D" Station>

(Station E)

The site for Station E has been selected in accordance with the new residential town development plan offered by the State Government.

Station E is planned at the center of the new residential town as one of major component facilities at the town center.

(Leon Station and Station F)

In planning construction of the new railway in the central urban area of Leon, the following matters have been considered aside from preconditions and basic policy as aforestated.

a) It is anticipated that Leon City would have a closer relationship with Silao City than with San Francisco del Rincon. Therefore, it is necessary to establish the terminal station considering the facts that there is a possibility of shuttle operation from Leon toward Silao and that there is a higher probability of tentative opening to the traffic at the earliest possible date in the section from Leon to Silao rather than in the section from Leon to the terminating point of the line (San Francisco del Rincon Station).

b) It is necessary to establish the station near the central urban area, in so far as it is possible, for the convenience of the public who utilize the station, because the urban area of Leon is much larger (radius of about 5 km) than any other city.

Considering all such matters, it is planned to construct Leon Station near the center of the urban area and to make Station F the terminal station. Each site for those stations is selected considering the following points.

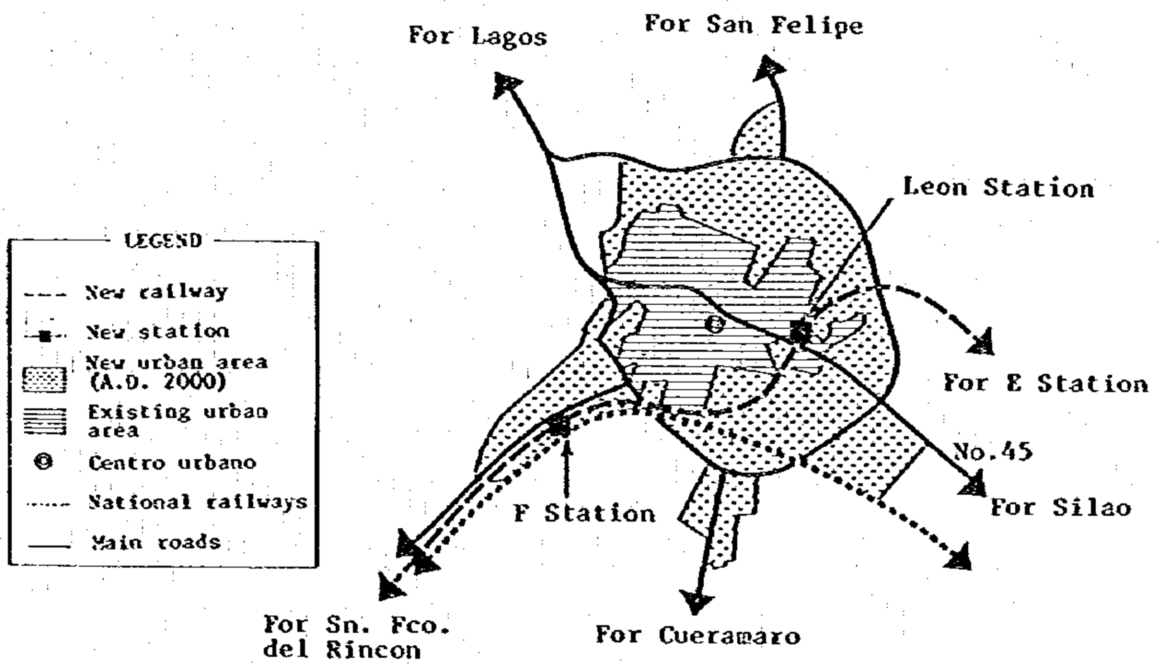
(Leon Station)

a) The site is situated close to the center of the urban area of Leon and, furthermore, in a well-balanced position.

b) Land can be secured to provide sufficient space for siting of station-associated facilities (such as station plaza, etc.).

c) The site is situated near (about 450 m) the terminal for interurban buses (only one now in existence in Leon City).

d) The site is near (about 250 m) the most important road in the urban area (National Highway No. 45).



<Leon and F Station>

(Station F)

The reasons behind the plan to establish Station F as the terminal station may be explained as follows.

a) Because Leon Station will be situated close to the center of the existing urban area and the station will be established on the viaduct, the costs of construction and land acquisition would be increased significantly if the station is designed with the terminal function. Therefore, the station with the terminal function has been planned for construction at ground level on a separate site where the construction cost can be reduced due to the relatively low land acquisition cost.

b) Notwithstanding the basic principle for the interurban railway that each city should be limited to only one station, the station with the complementary functions to Leon Station has been planned in the southwestern part of the urban area which is being developed for urbanization (mixed land utilization area). The urban area population of Leon is expected to grow to 1.6 million with an area expansion to 8,000 ha.

The reasons for siting Station F in the southwest of the urban area are as follows:

c) Considering the necessity to secure functions complemental to Leon Station, the Station F site can be expected to serve as the future base point in the new urban area extending to the southwest, while Leon Station's main radius of persons utilizing a particular station covers the existing urban area and the new urban area (at north, east and south).

d) Sufficient land to construct the station with terminal function can be acquired with relative ease.

e) The site is located near the main road within the urban area.

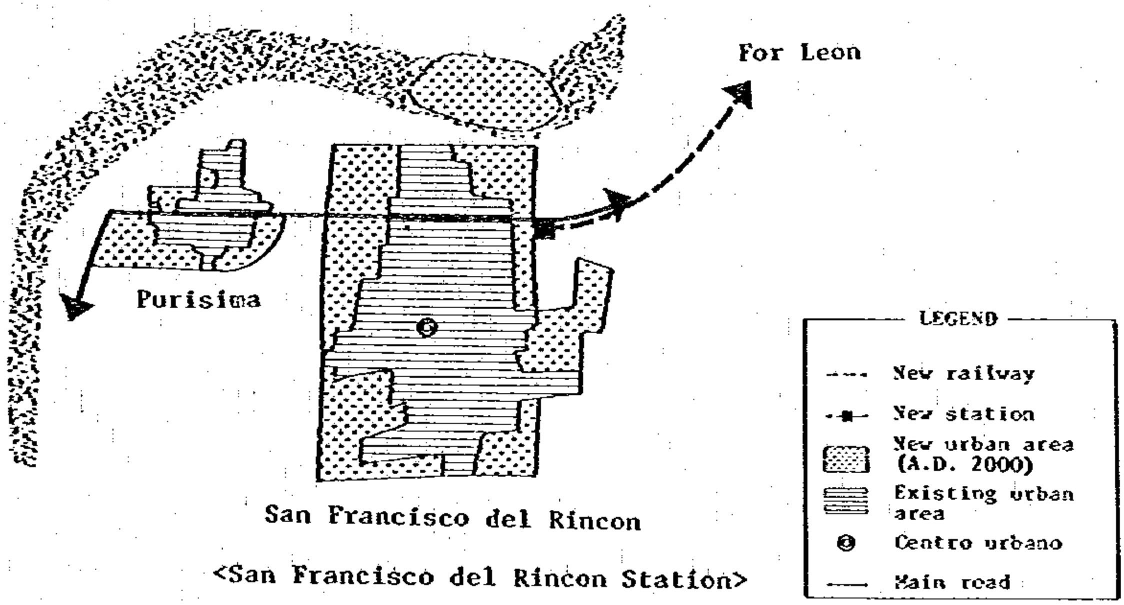
(San Francisco del Rincon Station)

The San Francisco del Rincon Station site has been selected for the following reasons:

a) The proposed site is near the main road interconnecting both San Francisco del Rincon City and Leon City.

b) The site is also near the most important road existing between the urban areas of San Francisco del Rincon and Purisima.

c) The site is close to the center of the urban area of San Francisco del Rincon.



<San Francisco del Rincon Station>

3-3 Route Selection

The route has been selected, in accordance with the following basic policy from station to station as proposed under the station location plan as stated in 3-2-2.

Route selection is based mainly on a 1/50,000 map and, when necessary, site observation.

3-3-1 Basic policies for route selection

Prior to route selection, the basic policy had been established as follows with due reference to the preconditions as stated in 3-1 and after full comprehension of the land utilization plan, land utilization status, and other conditions of topography, roads, and existing railways.

(1) In order to restrain construction costs to the possible minimum

1) The roadbed should be embanked as low as possible.

2) The crossings with other transport system such as existing railways and main roads should be kept to minimum.
When crossings cannot be avoided, the crossing should be elevated. Crossings with light traffic roads may be designed as grade crossings.

(2) Routes should not separate agricultural fields and urban areas, as possible, nor should they pass through excellent agricultural fields.

(3) Stations should be connected via the shortest possible route.

(4) The continuous viaduct system of a minimum required length should be designed in the urban area to keep the smooth urban functions.

3-3-2 Route selection

The route selected in accordance with Item 3-3-1 and the construction standards referred to in 7-2 are shown in Fig. 3-3-1. Please refer to the attached plan and profile views for further details.

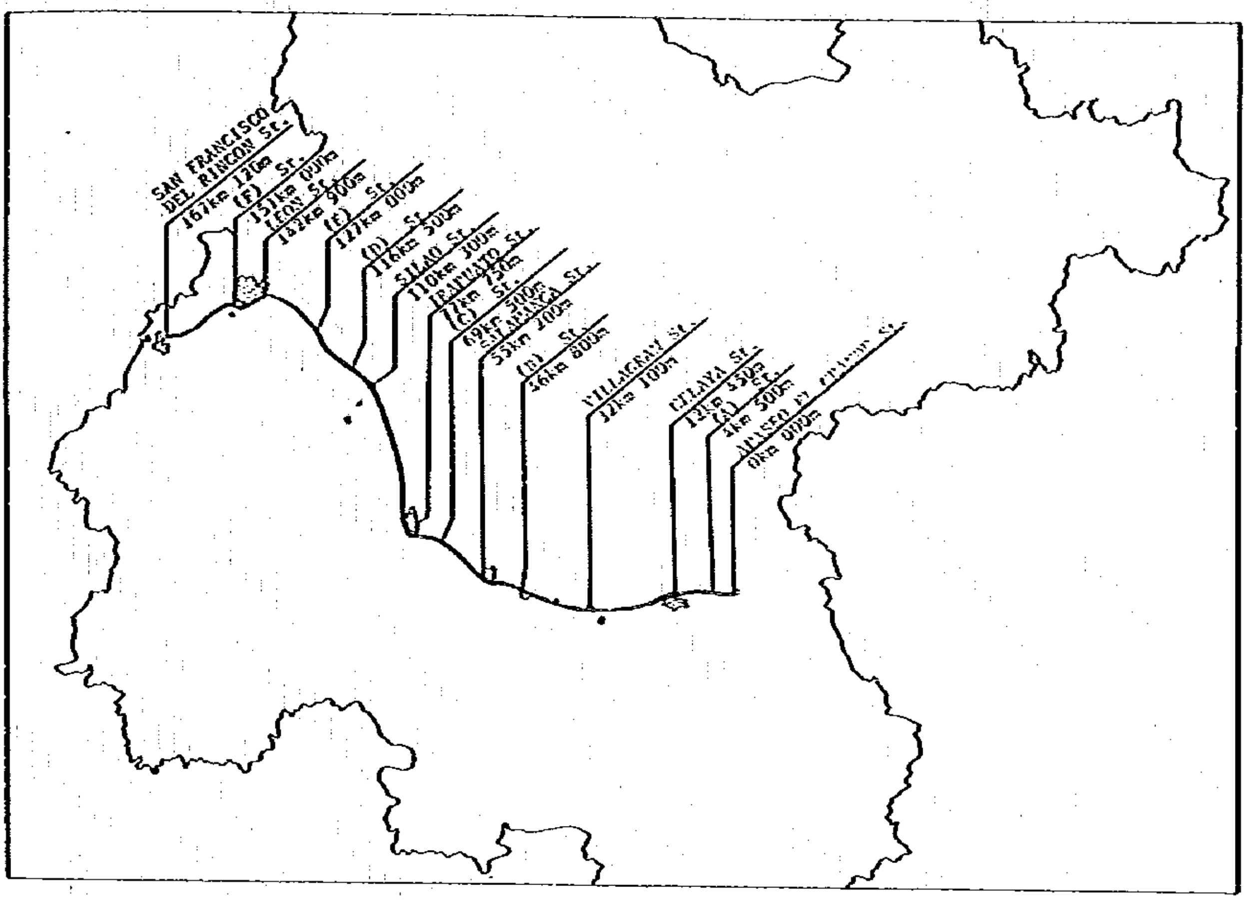


Fig. 3-3-1 Route Plan

ALTERNATIVES
CHAPTER 4

CHAPTER 4 ALTERNATIVES

In this feasibility study, alternatives to be examined hereafter are drafted in the form of alternative implementation programs by considering scheduled operation commencement years and proposed construction sections.

Although there can be other factors to be considered additionally in selecting the alternatives, such as route location and motive power system for example, it is assumed here that the route location is limited to the one as stated in the preceding chapter and the motive power system is the electrified system as selected after the comparative study in Chapter 6.

4-1 Preconditions for Alternative Making

Following preconditions are considered in selecting the alternatives.

(1) The traffic capacity of the existing roads between Silao and Leon and between Irapuato and Silao will become saturated by 1995 and 2000 respectively. It is therefore necessary that the railway should be operating commercially not later than those estimated time limits.

(2) The new residential town to be constructed between Silao and Leon is planned for a total population of about 160,000 by A.D. 2000. Into this new town, the State Government intends to stimulate the migration of the population and also intends to establish industries in the new industrial complex, near Irapuato City and between Celaya City and Apaseo el Grande City, and, furthermore, to create balanced growth of each city in the Corridor, mainly by means of the proposed railway. Therefore, the railway should begin commercial operation as early as possible.

So the railway construction is planned to begin in 1984. However, a minimum five-year period is required for preparatory works (establishing organization, surveying land, and designing), land acquisition, construction, and lead time for test operation, commissioning, and personnel training; the earliest possible opening year would be 1990.

(3) Construction works should be executed step-by-step by converting single track into double track, in accordance with the increases of passenger transportation demand.

(4) During the project lifetime, sections where passenger transportation demand is extremely small may not be constructed.

4-2 Alternatives

In view of the above preconditions, the following two alternative scheduled operation commencement years and two alternative proposed construction sections are considered.

1) Scheduled operation commencement year

1990 or 1995

2) Proposed construction section

The whole section between Apaseo el Grande and San Francisco del Rincon or the limited section from [A] to [F].

Thus, the following three alternative cases (implementation programs) are selected for comparison from among all the combinations.

These three cases are outlined as follows:

Case 1: (Scheduled operation commencement in 1990, completing the whole section)

Both scheduled operation commencement year and construction section are divided into three stages, duly considering the increasing trend of transportation demand and financing arrangements (Table 4-2-1). These are double track operation between [F] and Silao and single track operation between Silao and Salamanca from 1990 to 1994 (Stage 1), single track operation throughout the rest of the whole section with double track operation between [F] and Silao from 1995 to 1999 (Stage 2), double track operation throughout the whole section after 2000 (Stage 3). Since the sections except the portion from Silao to [F] will be operated as single track up to the year 1999, the signal stations will be provided for the single-track section to ensure sufficient track capacity (the same is applicable to Case 2 and Case 3).

Case 2: (Scheduled operation commencement in 1990, completing the partial section between [A] and [F])

Two sections from Apaseo el Grande to [A] and from [F] to San Francisco del Rincon will be excluded from the proposed railway construction because of their extremely small transportation demand. Both scheduled operation commencement year and construction section will be divided into three stages as same as in Case 1 (Table 4-2-1).

Case 3: (Scheduled operation commencement in 1995, completing the whole section)

Scheduled operation commencement year is divided into two stages with the simultaneous construction of the whole section starting from 1984. The railway will begin commercial operations by 1995 with double track for the section between Silao and [F] and with single track for the rest (Stage 2). Single track will be converted to double track in the second stage and double track operation for the whole section will start from 2000 (Stage 3) (Table 4-2-1).

Besides those three cases mentioned above, the fourth case will be considered which will be scheduled for operation commencement in 1995 by completing the section between [A] and [F]. However, this case has not been examined in the study hereafter, since it can be easily evaluated by comparison with preceding three cases.

Table 4-2-1 Alternatives

Case	Stage	Year	Sn. Fco. del Rincon	F	Leon	Silao	Irapuato	Salamanca	Celaya	A	Apaseo el Grande	Construction or Operation Start Year
Case 1		1984 ~ 1989										Construction in 1984
	Stage 1	1990 ~ 1994										Operation in 1990 Construction in 1990
	Stage 2	1995 ~ 1999										Operation in 1995 Construction in 1995
	Stage 3	2000 ~										Operation in 2000
Case 2		1984 ~ 1989										Construction in 1984
	Stage 1	1990 ~ 1994										Operation in 1990 Construction in 1990
	Stage 2	1995 ~ 1999										Operation in 1995 Construction in 1995
	Stage 3	2000 ~										Operation in 2000
Case 3		1984 ~ 1994										Construction in 1984
	Stage 2	1995 ~ 1999										Operation in 1995 Construction in 1995
	Stage 3	2000 ~										Operation in 2000

Double track under construction — Double track in operation

Single track under construction — Single track in operation

Note: Stage 1 ... Partial operation
Stage 2 ... Full operation with single track throughout the route (Partial double track)
Stage 3 ... Full operation with double track throughout the route

TRANSPORTATION DEMAND FORECAST
CHAPTER 5

CHAPTER 5 TRANSPORTATION DEMAND FORECAST

5-1 Outline of Forecast

The demand for passenger transportation on the new railway has been predicted in accordance with the flow chart, Fig. 5-1-1. The process can be summarized as follows.

1) Analysis of transportation demand at present and in the past
2) Building of forecast models based on the results in the foregoing subitem 1)
3) Forecast of total transportation demand based on future socio-economic conditions
4) Forecast of railway passengers based on future transportation networks
5) Forecast of peak period railway passengers according to the estimated peak ratio

Forecasts have been made for each of the alternative Cases 1 to 3, given in Chapter 4.

Forcasts are given for 1990, 1995, 2000 and 2010.

The forecast is based on the existing demand of bus passengers in the State of Guanajuato. Although it would be preferable to consider transportation demands other than for bus traffic alone, the relevant data are not available, but these figures can be considered safe, since almost all passengers travel from city to city by bus.

This forecast excludes through traffic and passengers coming from other states into Guanajuato. This is mainly because the necessary data are not available and it is considered rather unlikely that those passengers would utilize the new railway.

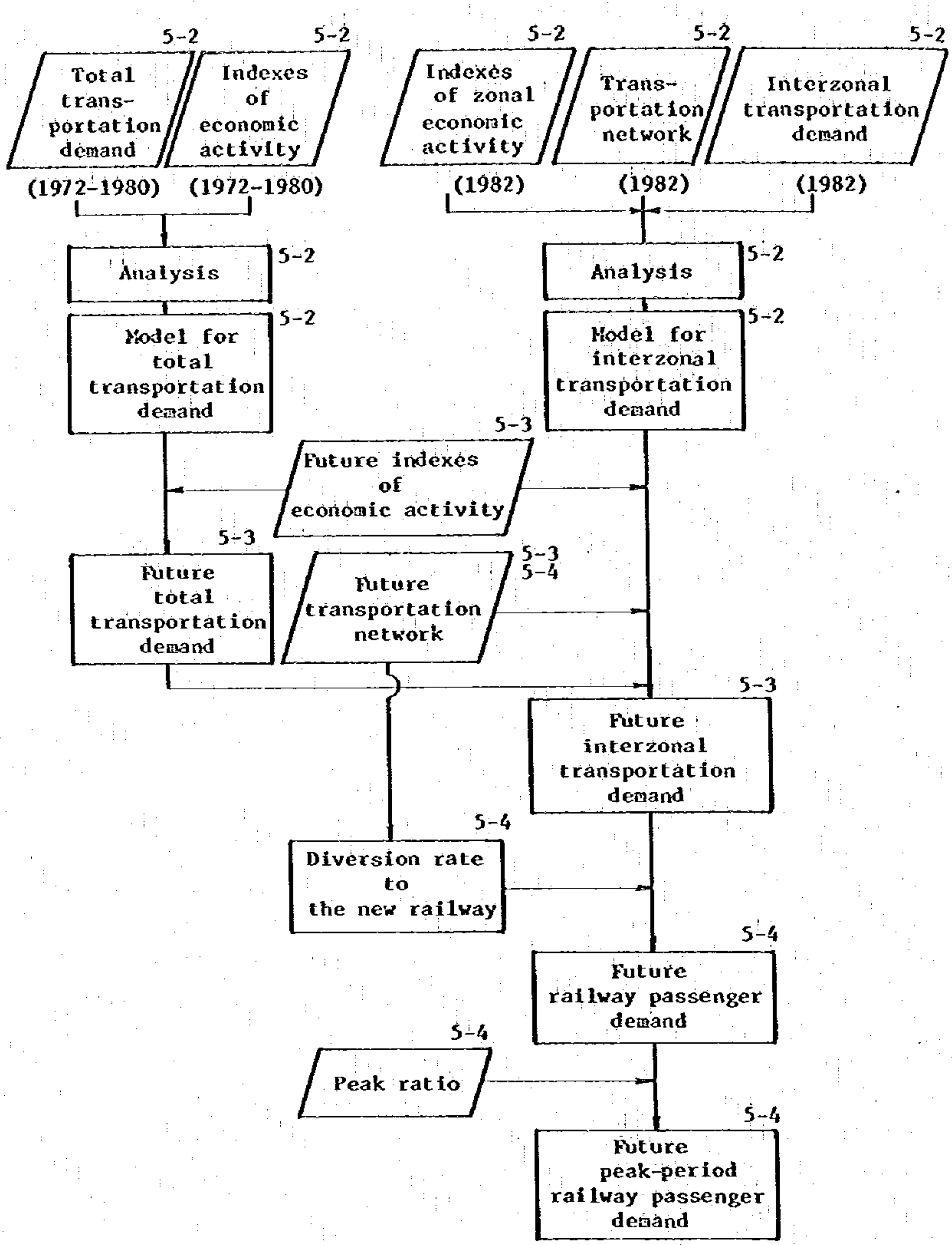


Fig. 5-1-1 Flow Chart of Transportation Demand Forecast

5-2 Analysis of Existing Transportation Demand

The process of the analysis of existing transportation demand comes under 5-2 in the flow chart of Fig. 5-1-1, including 1) analysis of the changing trend of total transportation demand over the years and its relationships with economic activities and 2) analysis of transportation demand on an interzonal basis within the State of Guanajuato. The explanatory models of transportation demand for the State of Guanajuato have been built through reference to the results of those analyses.

5-2-1 Analysis of total transportation demand

In order to forecast transportation demand in the future, the past process of growth in total transportation demand within the State of Guanajuato should be fully understood. However, relevant data are not available. Instead, transportation data of past nationwide trends available from the ATPF (Auto Transporte Publico Federal) have been analyzed. In this analysis, it has been assumed that the structural pattern of annual demand increase in the State of Guanajuato would be similar to that of the ATPF on a nationwide scale in Mexico.

Analysis has been conducted by explaining the transportation demand of the ATPF by both GDP and the total national population. The result is as follows:

$$PATPF = -635.1 + 2.039 \times GDP + 0.6686 \times PT$$

(Multiple correlation coefficient R = 0.98) .... (1)

Where, PATPF: ATPF's annual total of passengers transported (Million)

GDP: Gross Domestic Product of Mexico (1,000 Million Pesos, at 1970 price levels)

PT: Total national population (Million)

The data used for this analysis is from the statistical records for 1972 to 1980 (Appendix 5-1).

5-2-2 Analysis of interzonal transportation demand

(1) Interzonal demand

In order to estimate transportation demand, it is necessary to identify the points of departure and arrival for each person's trip, in addition to estimating the level of through traffic.

However, since there are many individual points of departure and arrival, statistical data have been combined in order to provide a workable analysis. Thus, the project area proposed for forecasting of transportation demand has been divided into several zones, each of which serves as the unit zone for those points of departure and arrival. Transportation demand is analyzed on an interzonal basis, rather than by individual points.

In this study, the whole State of Guanajuato is divided into 15 zones. The basis for this division is the OD Table of bus traffic passengers in 1982. Fig. 5-2-1 shows divided zones and the flow of bus passengers in excess of 1,000 persons per day between the zones (Appendix 5-2).

From Fig. 5-2-1, clearly there is a concentrated flow of passengers along the Bajio Industrial Corridor within the State of Guanajuato. There is also a conspicuous inflow and outflow of passengers between the Industrial Corridor and its environs, especially to and from Guanajuato City, the capital of the State.

Major traffic flow of passengers per day are as follows:

Salamanca	- Irapuato:	4,721 persons
Salamanca	- Santiago:	4,600 persons
Leon	- Silao:	4,569 persons
Celaya	- Acambaro:	4,447 persons
Guanajuato	- Leon:	4,067 persons

Names of municipios contained in each of the 15 zones of the State of Guanajuato are specified in Table 5-2-1.

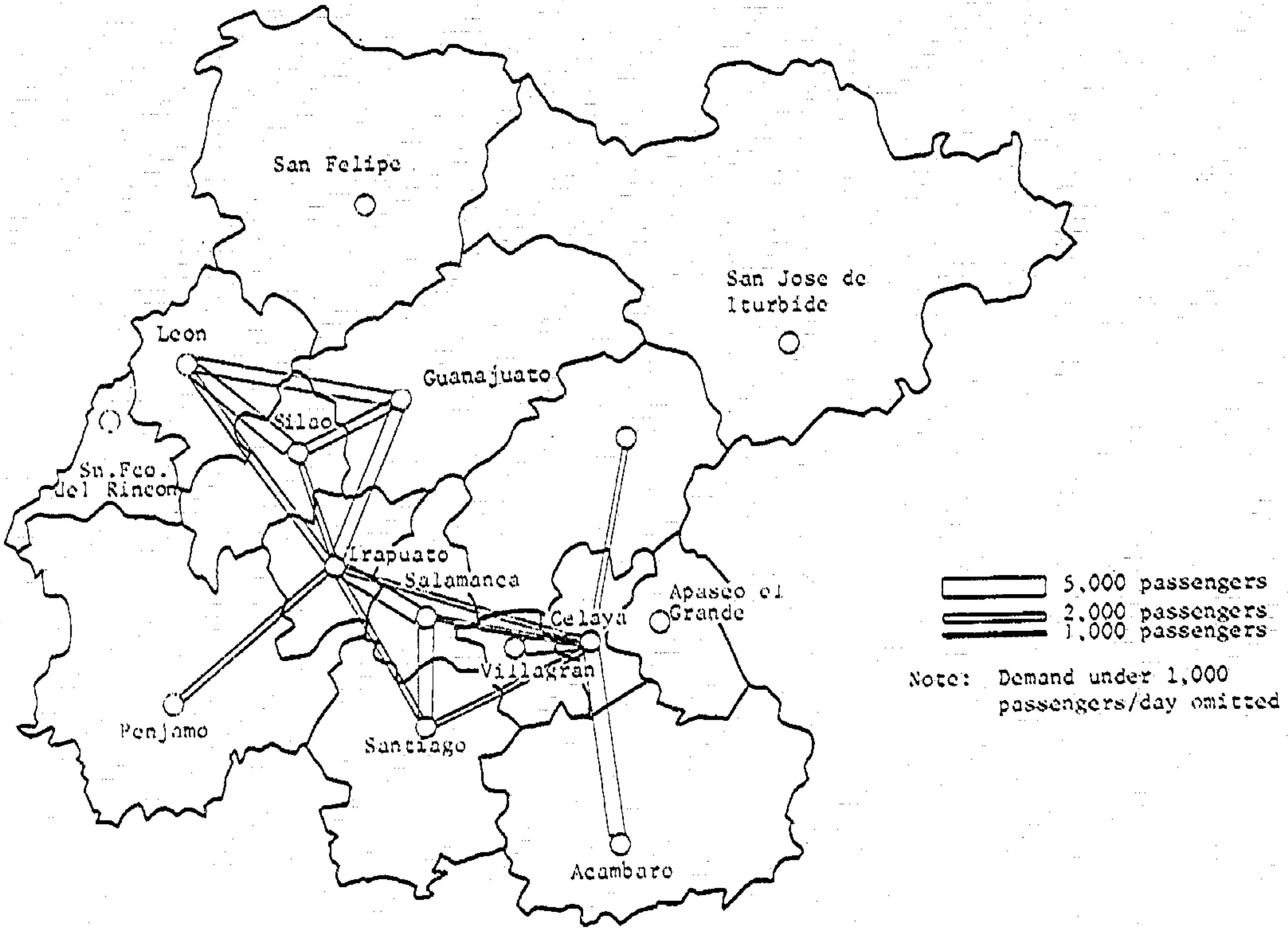


Fig. 5-2-1 Interzonal Transportation Demand in 1982 (Daily)

Table 5-2-1 Municipios of Each Zone

No.	Name of Zone	Center of Zone	Municipios
1	Apaseo el Grande	Apaseo el Grande	Apaseo el Grande, Apaseo el Alto
2	Celaya	Celaya	Celaya
3	Villagran	Villagran	Villagran, Cortazar
4	Salamanca	Salamanca	Salamanca
5	Irapuato	Irapuato	Irapuato
6	Silao	Silao	Silao, Romita
7	Leon	Leon	Leon
8	Sn. Fco. del Rincon	Sn. Fco. del Rincon	Sn. Fco. del Rincon, Purisima de Bustos
9	Acambaro	Acambaro	Acambaro, Coroneo, Jerecuaro, Tarimoro, Tarandacuao, Salvatierra, Santiago Maravatio
10	Valle de Santiago	Valle de Santiago	Valle de Santiago, Yuriria, Moroleon, Uriangato, Jaral del Progreso
11	Penjamo	Penjamo	Penjamo, Huanimaro, Abasolo, Cueramaro, Pueblonuevo, Ciudad Manuel Doblado
12	San Miguel de Allende	San Miguel de Allende	Allende, Comonfort, Santa Cruz de Juventino, Rasas
13	Guanajuato	Guanajuato	Guanajuato, Dolores Hidalgo
14	San Felipe	San Felipe	San Felipe, Ocampo
15	San Jose de Iturbide	San Jose de Iturbide	San Jose de Iturbide, Atarjea, Xichu, Victoria, San Luis de la Paz, Doctor Mora, Santa Catarina, Tierrablanca

(2) Analysis by gravity model

Normally, it is expected that the level of the transportation demand is influenced by the level of economic activities in each zone. It is also considered theoretically possible to determine the interzonal transportation demand in relation to demand generated in each zone and to economic distance (as resistance to the travel as represented in terms of travelling time, cost and other factors from zone to zone).

The gravity model is one of the models built by conversion of those theoretical conceptions into the equation as follows:

$$Tij = \alpha(Pi \cdot Pj)^{\beta} dij^{-\gamma} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where, Tij: Transportation demand between zone i and zone j

Pi: Population in zone i

dij: Economic distance between zone i and zone j

α, β, γ: Parameters

Equation (2) implies that the transportation demand between zones i and j would be proportional to the product of the population in zones i and j and in inverse proportion to the economic distance between the two zones i and j.

Analysis of interzonal transportation demand in this study has been conducted by application of the model of this type.

For application of equation (2), the necessary data are of three kinds:

1) Transportation demand by OD as expressed by Tij
2) Product of population by zones as expressed by Pi·Pj
3) Economic distance between zones as expressed by dij

Of these three, the data cited in 1) are from the OD Table of bus passengers in 1982 and the data in 2) come from the statistics on population by zones in 1982 as presented by the State Government of Guanajuato (Appendix 5-3).

As for the data referred to in 3), the following method has been used for calculation by reference to the road map and the existing bus service route network in the State.

Firstly, the travelling time by bus has been used as the economic distance between two zones. However, there is the question as to which point within the zone should be chosen as the basic point to calculate such travelling time. In this study, among the Municipios within the zone, the Municipio with the largest population in 1982 has been taken up as the core Municipio.

However, the zones of both Villagran and Guanajuato respectively have been excepted from the premised rules, because the former is near the Industrial Corridor and the latter is the capital of the State.

The Centro (the center of the Municipio) has been set as the basic zone center for calculation of the travelling time (Table 5-2-1).

Secondly, in order to calculate the travelling time of bus services, a network was established consisting of bus service lines of three categories by reference to the existing conditions of bus service in the State of Guanajuato (Appendix 5-4).

The bus services of the three categories are as follows:

1) Interurban bus
2) Local bus
3) Urban bus

For example, travelling time between zone i and zone j has been obtained from the following process.

It can be assumed that passengers would proceed from the center of zone i to the terminal of either interurban bus or local bus by urban bus. There, they may go to the bus terminal of zone j after changing to an interurban bus or local bus. Then, after one more transfer to an urban bus in zone j, they would arrive at the center of zone j. Travelling time includes all necessary time for this trip including time for transfer from bus to bus.

Although alternative routes may be implemented for interconnection between zone i and zone j, the minimum time requirement for the route has been chosen after taking all this into account.

The result, after analysis by use of the gravity model as shown in the equation (2) is shown in equation (3) and is modified to suit the analysis.

$$\text{Log } T_{ij} = -8.79 + 2.059 \times (\text{Log } P_i \cdot P_j) - 5.522 \times (\text{Log } d_{ij})$$

(Multiple correlation coefficient R = 0.78) .... (3)

5-3 Forecast of Future Transportation Demand

Forecast of future transportation demand corresponds to 5-3 in the flow chart as shown in Fig. 5-1-1. Future total transportation demand within Guanajuato is calculated using the data predicting the future transportation network and socio-economic situations as well as using the model described in 5-2. The result is the future transportation demand for bus transport, serving as basic data for computation of railway transportation demand in 5-4.

5-3-1 Forecast of total transportation demand

The purpose here is to seek the total volume of transportation demand within the State of Guanajuato. The result denotes the control total for the total volume of interzonal transportation demand as stated later in this Chapter. The forecast is made on the basis of the ATPF's model, expressed by Equation (1).

The ATPF's model deals with total transportation demand for the long-distance bus transportation in Mexico on a nationwide. Therefore, in order to apply this model to the State of Guanajuato, the above assumptions have been made. Then, the following measures have been taken in order to apply the model to the State.

Independent variables for the model are GDP and total population and the dependent variable is the total transportation demand of ATPF. To forecast future total volume of transportation demand, those variables have been increased in proportion to the future growth rate of both GDP and population in the State of Guanajuato as referred to in Chapter 1. Furthermore, total volume of transportation demand in the State of Guanajuato has been estimated by multiplying the existing transportation demand in the State of Guanajuato by the growth rate of the estimated value for ATPF.

5-3-2 Forecast of interzonal transportation demand

The first step is to forecast demand between 15 zones. The second is to forecast demand between more fractionalized zones with consideration of the railway stations to be newly established. In this report, the former is named 'forecast between large zones' and the latter 'forecast between small zones'.

(1) Transportation demand forecast between large zones

Forecast between large zones has been conducted for each zone OD by estimated future population in the State of Guanajuato and travelling time between each zone into Equation (3) as shown in (2) of 5-2-2.

Future population is shown in Table 5-3-1. Travelling time by bus at present, as shown in 5-2-2 (2), is used as the travelling time between zones in the future. Total volume of transportation demand, summed up for each zone OD from interzonal demand within the State of Guanajuato, has been adjusted to comply with the control total as forecasted in 5-3-1.

(2) Transportation demand forecast between small zones

Transportation demand between small zones has been forecasted by distributing the values of demand forecast between large zones in proportion to the population of each small zone. However, for forecast of transportation demand between small zones existing in one large zone, demand has been forecasted by the same method used between large zones.

Demand forecast between small zones accounts for new demand created by the new residential town, and the industrial complexes as mentioned in Chapter 1 and Chapter 2. However, because of the differences from existing demand, the forecast has been made by a different method from that already mentioned.

Firstly, with regard to the new residential town in the suburb of Leon City, the great majority of inhabitants are commuters working in secondary and tertiary industries. Thus, transportation demand in connection with other neighboring cities will most probably be much higher than the level of conventional interurban demand. Therefore, demand

Table 5-3-1 Future Population of Each Zone

(Unit: Person)

No.	Zone Name	1990	1995	2000	2010
1	Apaseo el Grande	103,000	117,000	131,000	161,000
2	Celaya	320,000	393,000	474,000	677,000
3	Villagran	124,000	147,000	170,000	226,000
4	Salamanca	242,000	303,000	374,000	557,000
5	Irapuato	402,000	509,000	635,000	969,000
6	Silao	143,000	158,000	171,000	199,000
7	Leon	1,110,000	1,485,000	1,942,000	3,262,000
8	Sn. Fco. del Rincon	111,000	126,000	140,000	170,000
9	Acambaro	396,000	444,000	489,000	582,000
10	Valle de Santiago	328,000	341,000	356,000	382,000
11	Penjamo	298,000	339,000	378,000	461,000
12	San Miguel de Allende	218,000	253,000	289,000	369,000
13	Guanajuato	225,000	255,000	285,000	349,000
14	San Felipe	95,000	102,000	108,000	118,000
15	San Jose de Iturbide	231,000	268,000	305,000	389,000
Total		4,351,000	5,241,000	6,246,000	8,870,000

(Source: The State Government)

which would be generated from the new residential town has been forecasted through reference to demand in similar residential towns in Japan. Factors obviously different from Japan or peculiar to Mexico, such as population composition by ages and population per household, have been considered.

Secondly, transportation demand for the industrial complexes proposed for construction at two sites has been forecasted by the following method.

Commuting demand has been estimated from the assumed working population in the industrial complexes and has been added to transportation demand between the industrial complex zone and the neighboring zones, taking into account present commuting pattern in the State.

(3) Result of demand forecast

According to the result of demand forecast of total bus passengers within the State of Guanajuato, it is estimated that the total passenger demand for bus transportation would reach a monthly total of 3,707,000 in 1990; 6,250,000 in 1995, 10,792,000 in 2000; and 20,431,000 in 2010, as shown in Fig. 5-3-1.

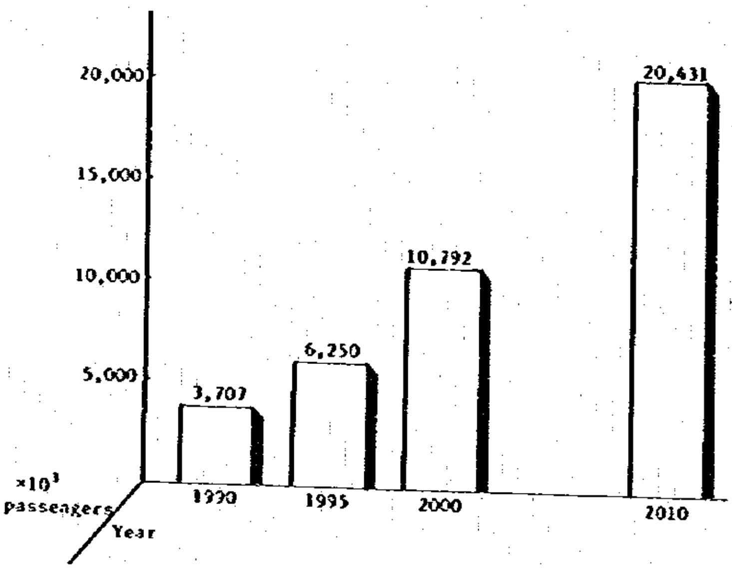


Fig. 5-3-1 Total Transportation Demand within the State of Guanajuato (Monthly)

Estimated interzonal transportation demand within the State of Guanajuato by 2000 is shown in Fig. 5-3-2. It clearly appears that even in 2000 there would be large interchange of traffic between zones along the Bajio Industrial Corridor, and also between these zones and Guanajuato zone. Transportation demand between all the zones within the State is shown in Appendix 5-5.

Cited below are the main items of daily transportation demand estimated for each zone OD:

Irapuato	- [C]:	39,900
Irapuato	- Salamanca:	38,000
Leon	- [E]:	35,700
Leon	- Irapuato:	27,900
Leon	- Guanajuato:	21,700
Leon	- Silao:	19,000

It should be noted, that each estimate as shown above includes probable new demand to be generated between the new residential town and the industrial complexes and their mother cities. Therefore, the estimated figure cannot be directly compared with the 1982 figures.

5-4 Forecast of Railway Passenger Transportation Demand

Forecast of transportation demand of railway passengers corresponds to part 5-4 in the flow chart, Fig. 5-1-1. Future interzonal bus passengers as forecasted by 5-3 is divided into demand of both railway and bus respectively. This is done by use of the diversion curve and the traffic service conditions of railway and bus between zones based on the assumed future traffic network. Railway passengers demand at peak period is estimated by application of the peak ratio. All those forecast results are referred to in later chapters.

5-4-1 Estimation of diversion curve

Potential diversion of estimated demand from bus to future railway transport depends ultimately upon the difference between the railway and bus transport services.

General indexes, or indicators, of the transportation service may be represented by travelling time, fare rate, punctuality, and comfort.

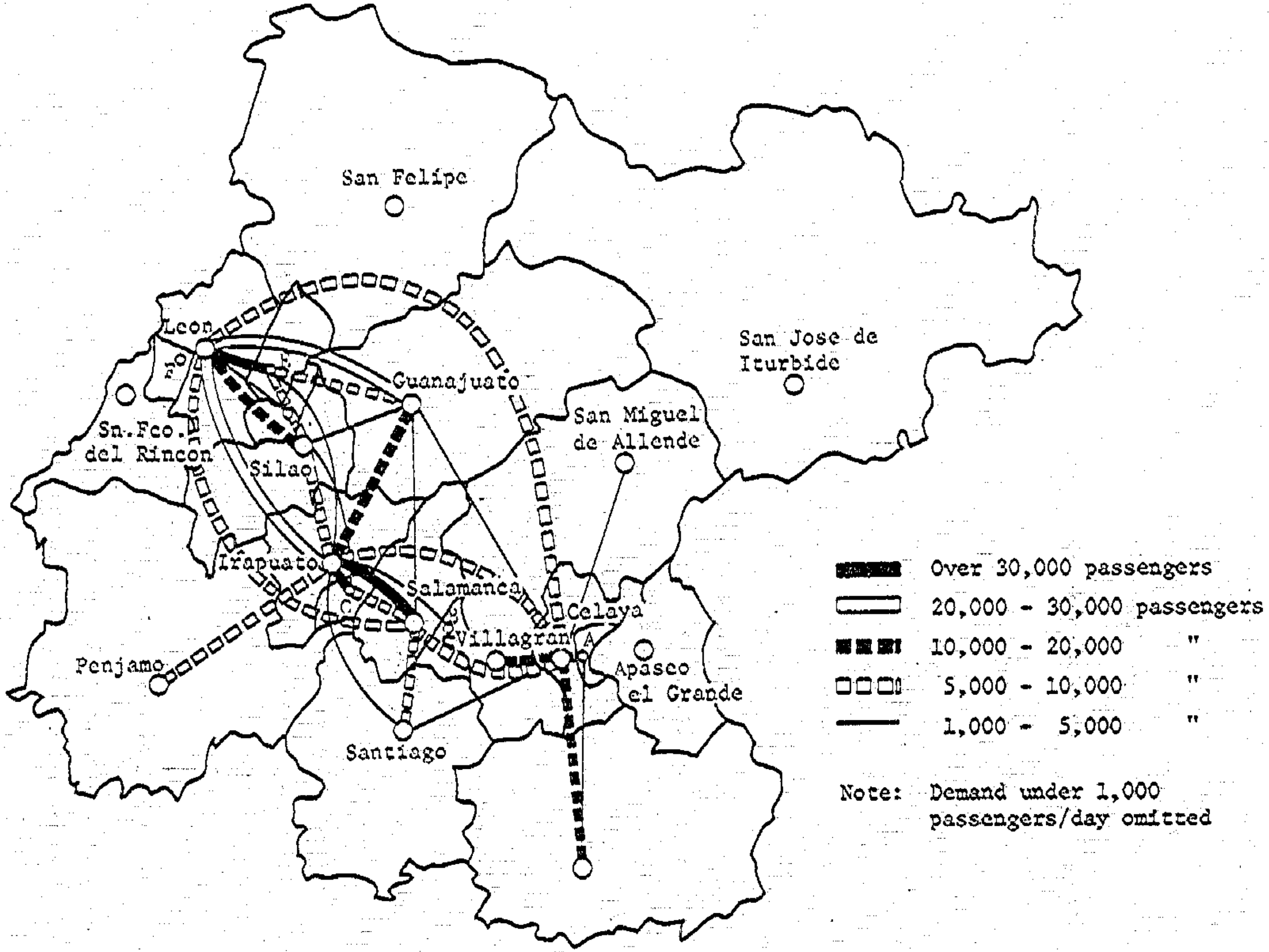


Fig. 5-3-2 Interzonal Transportation Demand in 2000 (Daily)

Transportation demand for railway and bus should be accounted for by use of a general index combining all the above factors. Nevertheless, travelling time has been chosen from among them as the sole index in this study. Therefore, possible diversion of passenger demand from bus to railway (after the commencement of operation of the new railway) should naturally be determined by comparing the travelling times of railway and bus, this being determined, not for total transportation demand, but for each zone OD.

There are various ways in which to determine the diversion rate due to different travelling time between zones. In this study, the time-ratio diversion curve method has been adopted. This is based upon the theory that transportation demand for a certain mode may be determined from the ratio of travelling time for competing transport modes, in this study, railway and bus. Fig. 5-4-1 shows the diversion curve used for this study.

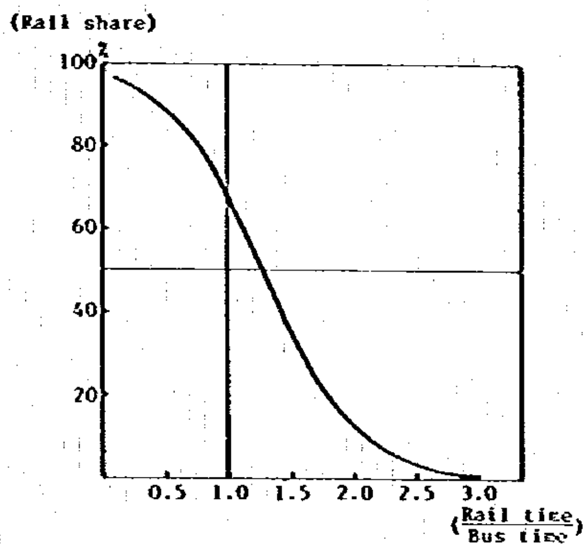


Fig. 5-4-1 Diversion Curve to the New Railway

The diversion curve, shown in Fig. 5-4-1, should be estimated by comparison of travelling time between railway and bus and the share of railways in Mexico. However, since there is no railway in Mexico similar to that proposed under this project, the curve has been estimated from the result of the questionnaire from the preceding field survey in the State of Guanajuato and also by reference to the diversion curve available in Japan.

The diversion curve thus estimated can be also expressed by the following function.

$$\left.\begin{aligned} Sij^R &= \frac{e^{f(x)}}{1 + e^{f(x)}} \\ f(x) &= 3.471 - 2.708 \times Rij \end{aligned}\right\} \cdots\cdots\cdots (4)$$

Where, Sij^R: Railway share between i and j zones

Rij: Travelling time ratio of railway versus bus between i and j zones (travelling time by railway/travelling time by bus)

5-4-2 Assumption for calculation of travelling time

In order to determine railway transportation demand by application of the diversion curve, it is necessary to calculate travelling time between zones by railway and bus. This can be determined from the traffic network assumed for the future.

The operating sections of the new railway are indicated for each alternative case by years in Chapter 4. Travelling time from station to station is specified in Chapter 6.

Basically, travelling time between zones by railway is calculated from the above factors. However, since the railway service is a station to station transport, the bus service has been assumed as the available means for access traffic. The access bus is therefore assumed to be the means of connection from the center of each zone to the nearest railway station without any transfer for the sake of passengers' convenience. Therefore, travelling time from i zone to j zone by railway has been calculated as follows.

It is assumed a passenger would arrive at the railway station by means of the access bus from the center of zone i, then continue his journey by railway, and arrive at the center of j zone by means of the access bus from the nearest station. Travelling time (including transfer time) is computed as total time required for his trip.

Travelling time between zones by bus is used as calculated in 5-2-2 (2).

5-4-3 Result of forecast

Passenger transportation demand for the railway is calculated by multiplying total transportation demand between zones for each stage by the railway share (as may be obtained by the diversion curve).

Annual railway transportation demand thus calculated in Case 1 is shown in Fig. 5-4-2.

Table 5-4-1 shows the number of passengers per day passing from station to station for each alternative case, each year. Table 5-4-2 shows the number of passengers per day embarking and disembarking at each station. Refer to Appendix 5-6-9 for estimated transportation demand for each OD.

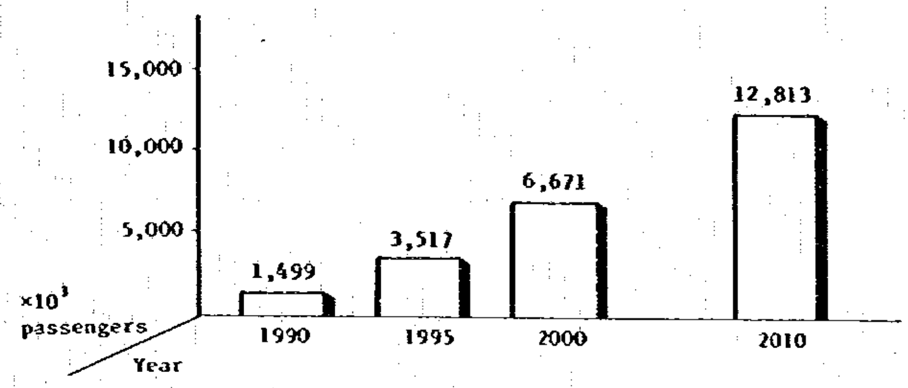


Fig. 5-4-2 Estimates of Railway Passengers Demand (Case 1)

Table 5-4-1 Railway Passenger Demand between Stations (Daily)

(Unit: 100 persons)

Case	Case 1						Case 2						Case 3					
Year	1990	1995		2000		2010	1990	1995		2000		2010	1990	1995		2000		2010
Stage / Station	1	1	2	2	3	3	1	1	2	2	3	3	1	1	2	2	3	3
Apaseo el Grande – [A]	—	—	7	10	11	19	—	—	—	—	—	—	—	—	7	10	11	19
[A] – Celaya	—	—	108	180	181	225	—	—	107	179	180	223	—	—	108	180	181	225
Celaya – Villagran	—	—	217	341	356	779	—	—	217	341	356	779	—	—	217	341	356	779
Villagran – [B]	—	—	132	216	230	559	—	—	132	216	230	558	—	—	132	216	230	559
[B] – Salamanca	—	—	145	236	251	611	—	—	145	236	251	611	—	—	145	236	251	611
Salamanca – [C]	154	277	299	532	568	1,359	154	277	299	532	568	1,359	—	—	299	532	568	1,359
[C] – Irapuato	194	354	375	711	745	1,528	194	354	375	711	745	1,527	—	—	375	711	745	1,528
Irapuato – Silao	150	270	280	492	530	1,479	150	270	280	492	530	1,479	—	—	280	492	530	1,479
Silao – [D]	232	418	421	741	759	1,956	232	418	421	741	759	1,956	—	—	421	741	759	1,956
[D] – [E]	235	424	427	753	770	1,978	235	424	427	753	770	1,978	—	—	427	753	770	1,978
[E] – Leon	265	498	501	936	952	2,119	265	498	501	936	952	2,119	—	—	501	936	952	2,119
Leon – [F]	9	15	16	27	28	70	9	15	15	27	27	68	—	—	16	27	28	70
[F] – Sn. Fco. del Rincon	—	—	3	4	5	8	—	—	—	—	—	—	—	—	3	4	5	8

Table 5-4-2 Arrivals and Departures of Railway Passengers for Each Stations (Daily)

(Unit: 100 persons)

Case	Case 1						Case 2						Case 3					
Year	1990	1995		2000		2010	1990	1995		2000		2010	1990	1995		2000		2010
Station / Stage	1	1	2	2	3	3	1	1	2	2	3	3	1	1	2	2	3	3
Apaseo el Grande	—	—	7	10	11	19	—	—	—	—	—	—	—	—	7	10	11	19
[A]	—	—	103	172	173	209	—	—	107	179	180	223	—	—	103	172	173	209
Celaya	—	—	262	420	434	805	—	—	262	419	432	803	—	—	262	420	434	805
Villagran	—	—	92	137	138	246	—	—	92	137	138	246	—	—	92	137	138	246
[B]	—	—	17	28	28	71	—	—	17	28	28	71	—	—	17	28	28	71
Salamanca	154	277	261	459	485	1,106	154	277	261	459	485	1,106	—	—	261	459	485	1,106
[C]	77	152	153	358	361	400	77	152	153	358	361	400	—	—	153	358	361	400
Irapuato	233	427	438	828	874	1,964	233	427	438	828	874	1,964	—	—	438	828	874	1,964
Silao	187	304	315	495	509	920	187	304	315	495	509	920	—	—	315	495	509	920
[D]	11	16	16	23	23	40	11	16	16	23	23	40	—	—	16	23	23	40
[E]	65	168	168	439	440	597	65	168	168	439	440	597	—	—	168	439	440	597
Leon	262	493	496	926	943	2,094	262	493	496	926	942	2,093	—	—	496	926	943	2,094
[F]	9	15	13	23	24	62	9	15	15	27	27	68	—	—	13	23	24	62
Sn. Fco. del Rincon	—	—	3	4	5	8	—	—	—	—	—	—	—	—	3	4	5	8

5-4-4 Forecast of peak period transportation demand

Forecast of transportation demand at peak periods is necessary to formulate the train operation diagram, design the station buildings, and plan the station plazas.

In this study, the recorded data available from the Metro in Mexico City has been used as the data representing the daily fluctuation in transportation demand necessary to calculate demand at peak period (Appendix 5-10). Since the railway under this study is different in character from the existing Metro system in Mexico City, it is not expected that the daily fluctuation of transportation would necessarily be exactly same as in the case of Metro. However, in consideration of local labor practices in Mexico, such data are more suitable than similar data available in other countries.

Peak period transportation demand may be calculated by multiplying the full day transportation demand for the railway by the concentration rate of demand during peak period. In applying the peak ratio, direction of flow must be taken into consideration. During the morning rush hours, the peak in the flow of commuters going to their offices, factories or schools from their residential is larger than the flow in the opposite direction. During the evening rush hours, the opposite applies.

In this study, the peak ratio for each OD has been applied, assuming the larger population zones to be working places. However, the relationship between the new residential towns and the industrial complexes are excluded from this principle. In all of these cases, commuters are assumed to live in new residential towns and work in industrial complexes.

The forecast results are shown in Table 5-4-3 (Cases 1 & 3) and Table 5-4-4 (Case 2) respectively. The peak ratio has been taken from data recorded in the Metro with 18:00 to 19:00 as the peak period and 12:00 to 13:00 as the off-peak period.

Table 5-4-3 Railway Passenger Demand between Stations (Case 1, Case 3, Peak and Off-peak Period)

(Unit: Person/hour)

Station	1990				1995								2000								2010			
	Stage 1				Stage 1				Stage 2				Stage 2				Stage 3				Stage 3			
	Peak		Off-peak		Peak		Off-peak		Peak		Off-peak		Peak		Off-peak		Peak		Off-peak		Peak		Off-peak	
	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2
Apaseo el Grande	—	—	—	—	—	—	—	—	40	20	20	20	60	30	30	30	60	30	30	30	100	60	50	50
[A]	—	—	—	—	—	—	—	—	390	540	260	260	640	900	430	440	650	910	440	440	880	1,050	540	550
Celaya	—	—	—	—	—	—	—	—	860	1,000	530	530	1,370	1,560	830	830	1,440	1,610	860	870	3,280	3,400	1,890	1,890
Villagran	—	—	—	—	—	—	—	—	630	510	320	320	1,020	830	530	520	1,090	880	560	560	2,670	2,120	1,360	1,350
[B]	—	—	—	—	—	—	—	—	690	550	350	350	1,130	900	580	570	1,200	950	610	610	2,970	2,270	1,490	1,470
Salamanca	860	470	380	370	1,540	840	680	660	1,660	900	740	710	2,940	1,620	1,310	1,270	3,140	1,720	1,400	1,350	7,520	4,120	3,350	3,240
[C]	930	730	470	470	1,670	1,360	860	850	1,790	1,420	920	900	3,250	2,840	1,730	1,720	3,440	2,950	1,820	1,800	7,790	5,300	3,750	3,660
Irapuato	750	530	370	360	1,370	940	660	650	1,430	980	690	670	2,500	1,720	1,210	1,180	2,690	1,850	1,300	1,270	7,740	4,930	3,630	3,540
Silao	1,240	740	570	550	2,200	1,380	1,030	1,000	2,220	1,390	1,040	1,010	3,800	2,550	1,820	1,780	3,890	2,610	1,860	1,820	10,320	6,430	4,810	4,680
[D]	1,270	750	580	560	2,250	1,390	1,040	1,020	2,260	1,400	1,050	1,020	3,870	2,580	1,850	1,800	3,960	2,640	1,890	1,850	10,450	6,490	4,860	4,730
[E]	1,490	790	650	630	2,790	1,470	1,230	1,190	2,810	1,480	1,240	1,190	5,250	2,770	2,310	2,230	5,340	2,820	2,350	2,270	11,870	6,290	5,230	5,050
Leon	30	50	20	20	50	80	40	40	50	90	40	40	90	150	70	70	90	150	70	70	210	380	170	170
[F]	—	—	—	—	—	—	—	—	10	10	10	10	20	20	10	10	20	20	10	10	30	40	20	20
Sn. Fco. del Rincon																								

* All figures apply to Case 1. Figures for 1995 Stage 2, 2000 and 2010 also apply to Case 3.

Table 5-4-4 Railway Passenger Demand between Stations (Case 2, Peak and Off-peak period)

(Unit: Person/hour)

Station	1990				1995								2000								2010			
	Stage 1				Stage 1				Stage 2				Stage 2				Stage 3				Stage 3			
	Peak		Off-peak		Peak		Off-peak		Peak		Off-peak		Peak		Off-peak		Peak		Off-peak		Peak		Off-peak	
	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2	VIA1	VIA2
Apaseo el Grande – [A]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[A] – Celaya	-	-	-	-	-	-	-	-	380	530	260	260	630	900	430	440	640	900	430	440	870	1,040	540	540
Celaya – Villagran	-	-	-	-	-	-	-	-	860	1,000	520	530	1,370	1,560	830	830	1,440	1,610	860	870	3,270	3,400	1,890	1,890
Villagran – [B]	-	-	-	-	-	-	-	-	630	510	320	320	1,020	830	530	520	1,090	880	560	560	2,660	2,120	1,360	1,350
[B] – Salamanca	-	-	-	-	-	-	-	-	690	550	350	350	1,130	900	580	570	1,200	950	610	600	2,970	2,270	1,490	1,470
Salamanca – [C]	860	470	380	370	1,540	840	680	660	1,660	900	740	710	2,940	1,620	1,310	1,270	3,140	1,720	1,400	1,350	7,520	4,120	3,350	3,240
[C] – Irapuato	930	730	470	470	1,670	1,360	860	850	1,790	1,420	920	900	3,250	2,840	1,730	1,720	3,440	2,950	1,820	1,800	7,780	5,300	3,750	3,660
Irapuato – Silao	750	530	370	360	1,370	940	660	650	1,430	980	690	670	2,500	1,720	1,210	1,180	2,690	1,850	1,300	1,270	7,740	4,930	3,630	3,540
Silao – [D]	1,240	740	570	550	2,200	1,380	1,030	1,000	2,220	1,390	1,040	1,010	3,800	2,550	1,820	1,780	3,890	2,610	1,860	1,820	10,320	6,430	4,810	4,680
[D] – [E]	1,270	750	580	560	2,250	1,390	1,040	1,020	2,260	1,400	1,050	1,020	3,870	2,580	1,850	1,800	3,960	2,640	1,890	1,850	10,450	6,490	4,860	4,730
[E] – Leon	1,490	790	650	630	2,790	1,470	1,230	1,190	2,810	1,480	1,240	1,190	5,250	2,770	2,310	2,230	5,340	2,820	2,350	2,270	11,860	6,290	5,230	5,050
Leon – [F]	30	50	20	20	50	80	40	40	50	80	40	40	80	150	60	70	90	150	70	70	210	380	160	170
[F] – Sn. Fco. del Rincon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

OPERATION AND ROLLING STOCK PLAN
CHAPTER 6

CHAPTER 6 OPERATION AND ROLLING STOCK PLAN

6-1 Operation Plan

6-1-1 Maximum speed

A maximum speed of 130 km/h was selected in order to secure an advantage over bus travelling time.

6-1-2 Selection of power system

There are two basic types of power system to be considered, electric and diesel, and two types of rolling stock to be considered, railcars and locomotive-hauled trains. These selections are to be based on comparative study of operating performance (acceleration, deceleration, and traveling time) and costs (initial investment and depreciation of an electrification system; running costs, such as fuel or power; and repair and maintenance cost).

Rolling stock capable of 130 km/h maximum operating speeds has been selected here so that service can be superior to that provided by the extensive network of bus lines. This requirement can be met by either electric or diesel power and by either railcar or locomotive propulsion, with very little difference in traveling time. Power costs are cheaper with electrification, even when depreciation of the electrification system is included, as illustrated in Fig. 6-1-1.

Railcars have several advantages of flexibility. They can be added to train consists easily as demand grows, without changing train operating performance. Conventional locomotive haulage, furthermore, requires locomotives to be uncoupled and run around passenger cars at each terminal or turnback station, and this requires additional time and personnel.

In view of these and other factors, an electric railcar system has been adopted for this project.

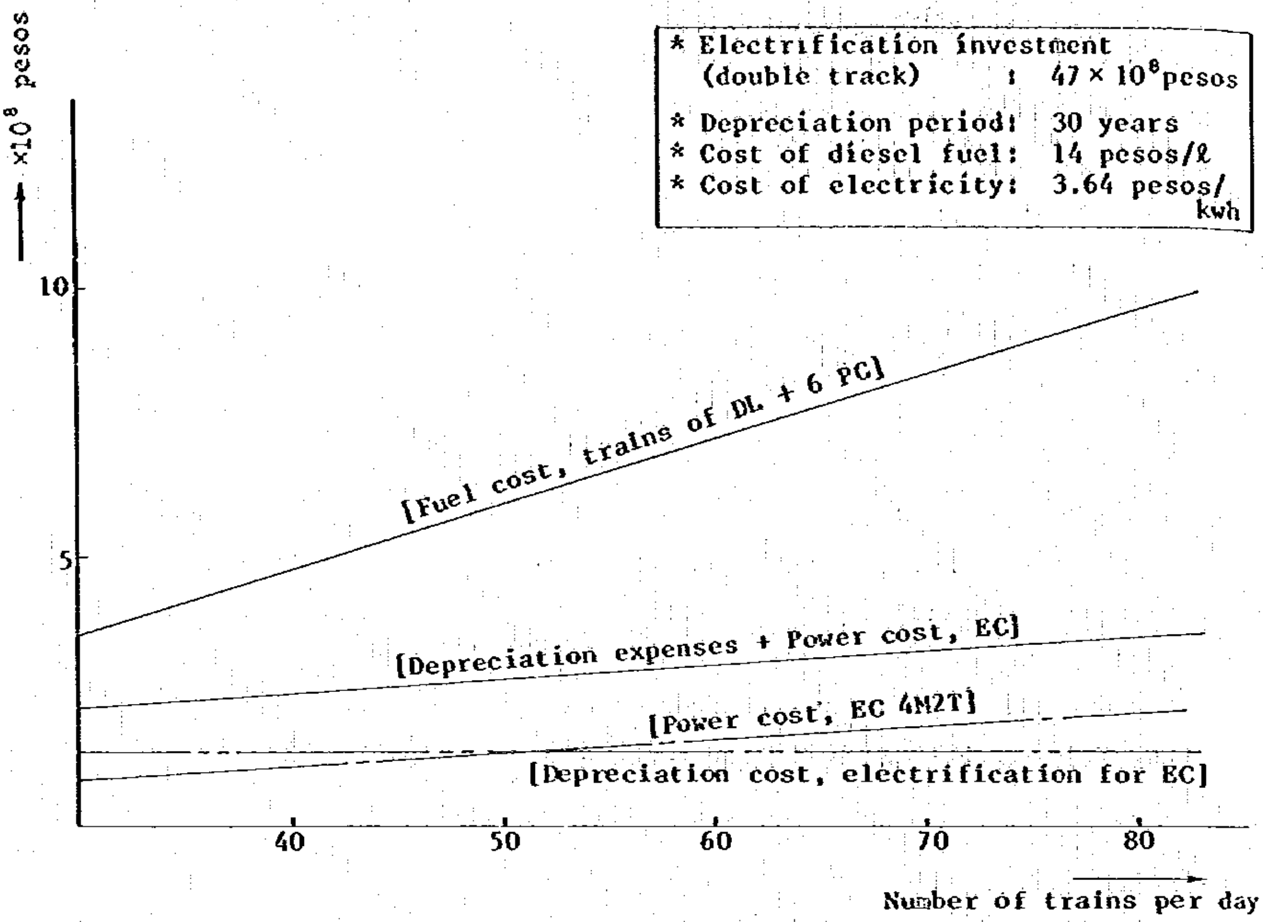


Fig. 6-1-1 Comparison of Power Costs

6-1-3 Operation line chart and standard running time

The operation line chart provides the basis for assessment of the standard running time of the trains, the train interval, and other details related to the operation plan.

The operation line chart is obtained as follows.

(1) First, the "speed versus distance curve", which expresses the theoretical variation of the speed of the train as a function of its movement is drawn, based on the performance of the rolling stock and the conditions of the track (gradient and curvature).

(2) Next, the "distance versus time curve", which expresses the relation between the passage of time and the movement of the train from station to station, is drawn based on the "speed versus distance curve", for calculating the running time required between successive stations.

(3) The standard running time is obtained by rounding off the required running time, in units of 15 seconds.

The flow chart of the procedure to draw the operation line chart is shown in Fig. 6-1-2.

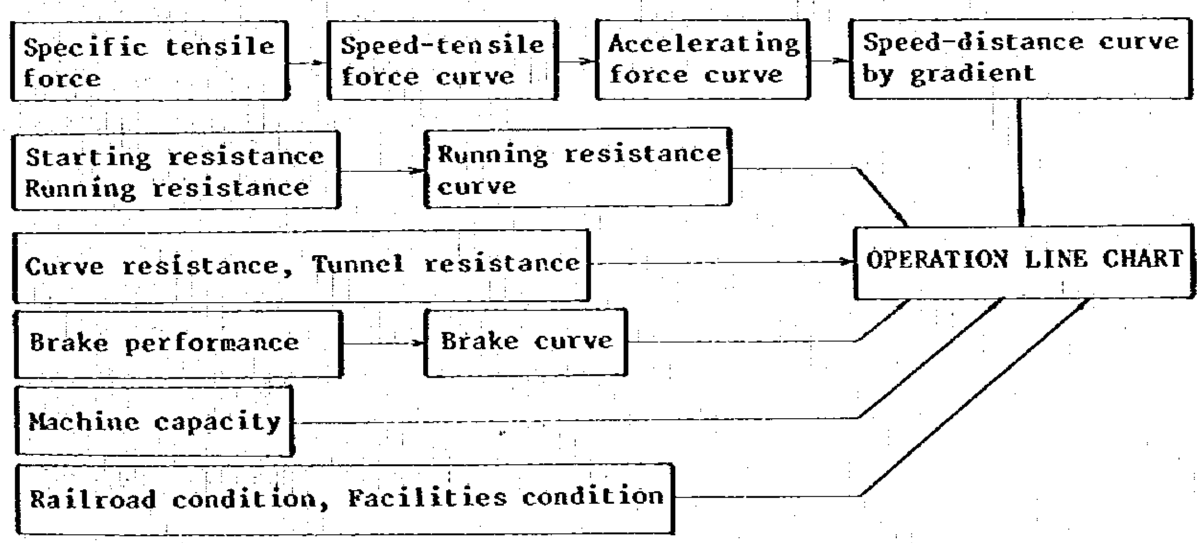


Fig. 6-1-2 Flow Chart to Draw the Operation Line Chart

The principal numerical data used in this project are shown below.

(1) Data related to the rolling stock

Train make-up:	4M2T (Practically the same performance is obtained for the distinct train formations taken into consideration in this project, i.e., 3, 6 and 9 cars.)
Weight:	265 tons (for a train with normal accommodation)
Average acceleration current:	440 A
Acceleration:	Up to 56 km/h speed 1.56 km/h/sec.
Deceleration:	When stopping at a station 2.50 km/h/sec.

(2) Speed limit

At curved sections:	There is no speed restriction on curved sections because the minimum radius of curvature is more than 1,000 m ($R \geq 1,000$ m) in view of the route location.
At turnouts :	Turnout number #12, 55 km/h (at the turnout side)

(3) Planned maximum speed 130 km/h

The standard running time, calculated on the basis of the operation line chart taking into consideration the above conditions, is shown in Table 6-1-1. (Operation line chart: Refer to Appendix 6-1.)

6-1-4 Running time

(1) Stopping time

It is assumed that approximately 30 seconds is sufficient for the passengers to get on and off the train. However, the stopping time is assumed to be 60 seconds at passing stations for single track operation and at some of the large stations.

For full double-track operation, it is presumed that it will be possible to shorten the stopping time in the stations of Irapuato and Leon, in consideration of actual operating experience.

Table 6-1-1 Standard Running Time List (Assuming Full Double Track)

To the North	Section		To the South
EC 4M2T	Station	Distance	EC 4M2T
	Apaseo		
3'45"	[A]	4.50 km	3'45"
5'15"	Celaya	7.95	5'15"
11'00"	Villagran	19.65	11'00"
8'30"	[B]	14.70	8'30"
5'30"	Salamanca	8.40	5'30"
8'15"	[C]	14.30	8'15"
5'15"	Irapuato	8.25	5'15"
17'00"	Silao	32.55	17'00"
4'30"	[D]	6.20	4'30"
6'30"	[E]	10.50	6'15"
9'30"	Leon	15.90	9'00"
5'15"	[F]	8.10	5'15"
9'00"	Rincon	16.12	9'15"
99'15"	Total	167.12	98'45"

(2) Travelling time

The running time is obtained by adding a margin of approximately 3 percent to the standard running time, calculated above.

The travelling time is obtained by adding the stopping time to the running time. The schedule speed is obtained dividing the distance by the travelling time.

The running time, stopping time, travelling time, and schedule speed are calculated according to the type of power system and type of track (i.e., single track and double track). (Refer to Appendixes 6-2 - 6-5.)

6-1-5 Types of trains

The railway planned along the "Bajio Industrial Corridor" is assumed to be basically an interurban transportation type railway. However, commuting transportation will be taken into consideration between [E] Station and Leon Station and between Salamanca Station and Irapuato Station.

There is the possibility of introducing the "rapid train service" and the "limited express train service" in the future. However for this project, only the local service train is taken into consideration, because the total length of the route is only 167 km and the travelling time is approximately 2 hours accounting for differences in double and single track.

6-2 Transportation Plan

6-2-1 Preparation of the transportation plan

The transportation plan is prepared by determining the transportation capacity required each year, calculated from the estimated transportation demand.

The following facts are considered in preparing the transportation plan.

(1) The volume of traffic is subject to fluctuations. Therefore, the transportation plan shall be prepared in such a way as to cope with the fluctuations of traffic volume according to the season, day of week, and period of time.

Particularly with regard to the period of time, the transportation capacity shall be planned in such a way to cope with the traffic volume of morning and evening peak hours and the traffic volume during the day time.

(2) In principle, the transportation capacity shall be decreased during the periods of time with a small volume of traffic, however, the transportation plan shall be prepared by considering convenience to the users.

(3) Any modification in the transportation plan normally requires a preparation period of approximately 2 years at least, because it involves changes in the number of rolling stock and train crew. Therefore, the transportation plan shall be prepared by considering a sufficient margin of spare capacity in order to cope with future evolutions of the traffic volume.

6-2-2 Traffic volume and transportation capacity

The transportation capacity of each case, corresponding to the traffic volume of each year based on the forecast of transportation demand, is shown in Fig. 6-2-1.

The standard congestion rate considered for the sake of calculating the transportation capacity is 200 percent of the normal accommodation during the peak hours and 100 percent during the day time. Normal accommodation is assumed to be 350 persons with a train make-up of 3 cars and 720 persons with a train make-up of 6 cars. The degree of congestion in each section is shown in Table 6-2-1.

6-2-3 Train operation diagram

Examples of train operation diagram based on the above plan are shown in Appendixes 6-6 and 6-7.

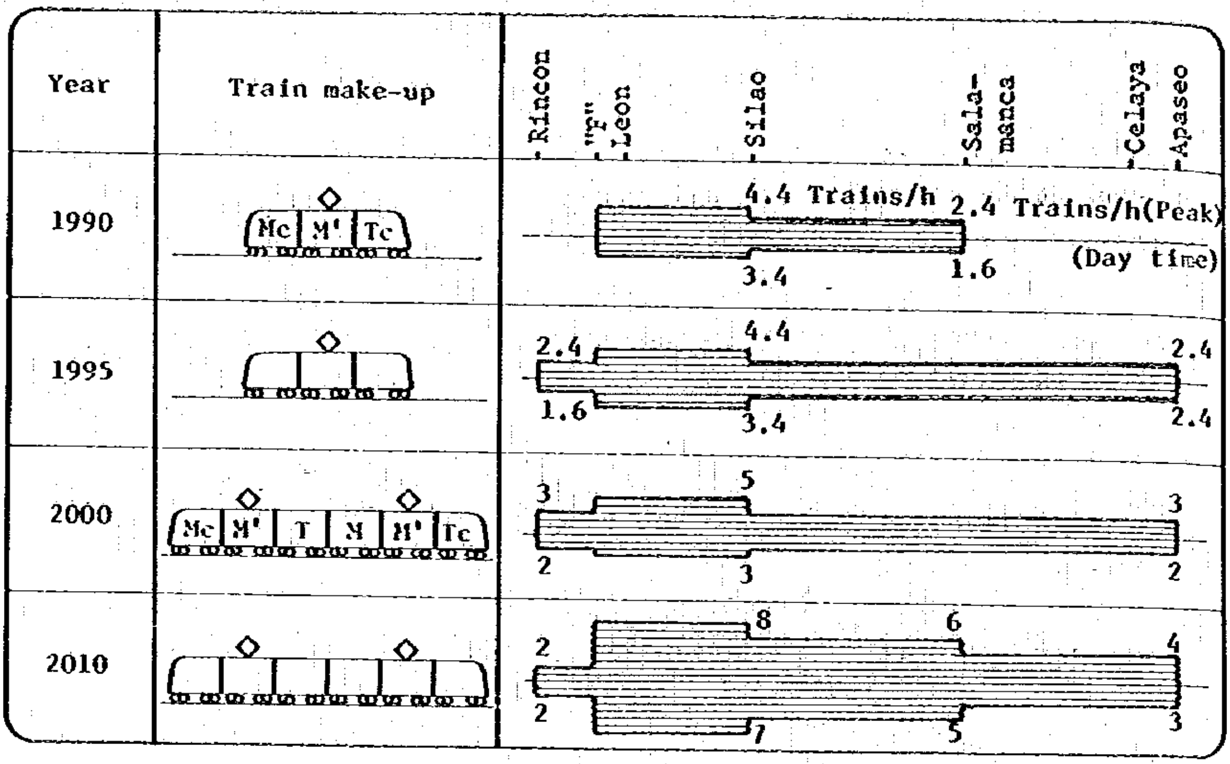


Fig. 6-2-1 Transportation Plan by Year (Case 1)

Note:

1. In Case 2, the operation section is between [A] Station and [F] Station.
2. In Case 3, the railway is assumed to start its operation in 1995 and the transportation plan is the same as Case 1.
3. Mc: Control motor car
   M : Intermediate motor car
   M': Intermediate motor car (with pantograph)
   T : Intermediate trailer car
   Tc: Control trailer car
4. Trains shown are trains each way per hour.

Table 6-2-1 Congestion Rate by Section (Case 1)

	1990						1995											
	Stage 1						Stage 1						Stage 2					
	Peak			Off-Peak			Peak			Off-Peak			Peak			Off-Peak		
	Volume of Traffic	Transportation Capacity	Rate of Congestion	Volume of Traffic	Transportation Capacity	Rate of Congestion	Volume of Traffic	Transportation Capacity	Rate of Congestion	Volume of Traffic	Transportation Capacity	Rate of Congestion	Volume of Traffic	Transportation Capacity	Rate of Congestion	Volume of Traffic	Transportation Capacity	Rate of Congestion
Apaseo													40	2.4 × 3c (840)	% 5	20	2.4 × 3c (840)	% 2
[A]													540	"	64	260	"	31
Celaya													1,000	"	119	530	"	63
Villagran													630	"	74	320	"	38
[B]													690	"	82	350	"	42
Salamanca	860	2.4 × 3c (840)	% 102	380	1.6 × 3c (560)	% 68	1,540	2.4 × 3c (840)	% 183	690	2.4 × 3c (840)	% 81	1,660	"	197	740	"	88
[C]	930	"	110	470	"	84	1,670	"	199	860	"	103	1,790	"	213	920	"	109
Irapuato	750	"	90	370	"	66	1,370	"	163	660	"	79	1,430	"	170	690	"	82
Silao	1,240	4.4 × 3c (1,540)	80	570	3.4 × 3c (1,190)	48	2,200	4.4 × 3c (1,540)	143	1,030	3.4 × 3c (1,190)	86	2,220	4.4 × 3c (1,540)	144	1,040	3.4 × 3c (1,190)	87
[D]	1,270	"	82	580	"	48	2,250	"	146	1,040	"	88	2,260	"	147	1,050	"	88
[E]	1,490	"	96	630	"	53	2,790	"	181	1,230	"	103	2,810	"	182	1,240	"	104
Leon	30	"	2	20	"	2	50	"	3	40	"	3	90	"	6	40	"	3
[F]													10	"	1	10	"	1
Rincon																		

	2000												2010					
	Stage 2						Stage 3						Stage 3					
	Peak			Off-Peak			Peak			Off-Peak			Peak			Off-Peak		
	Volume of Traffic	Transportation Capacity	Rate of Congestion	Volume of Traffic	Transportation Capacity	Rate of Congestion	Volume of Traffic	Transportation Capacity	Rate of Congestion	Volume of Traffic	Transportation Capacity	Rate of Congestion	Volume of Traffic	Transportation Capacity	Rate of Congestion	Volume of Traffic	Transportation Capacity	Rate of Congestion
Apaseco – [A]	60	2.4 × 6ᶜ (1,728)	% 3	30	2.4 × 6ᶜ (1,728)	% 2	60	3 × 6ᶜ (2,160)	% 3	30	2 × 6ᶜ (1,440)	% 2	100	4 × 6ᶜ (2,880)	% 4	50	3 × 6ᶜ (2,160)	% 2
[A] – Celaya	900	"	52	430	"	25	910	"	42	440	"	31	1,050	"	36	550	"	25
Celaya – Villagran	1,560	"	90	830	"	48	1,610	"	75	870	"	60	3,400	"	118	1,890	"	88
Villagran – [B]	1,020	"	59	530	"	30	1,090	"	50	560	"	39	2,670	"	93	1,360	"	63
[B] – Salamanca	1,130	"	65	580	"	34	1,200	"	56	610	"	43	2,970	"	103	1,490	"	69
Salamanca – [C]	2,940	"	170	1,310	"	76	3,140	"	145	1,400	"	97	7,520	6 × 6ᶜ (4,320)	174	3,350	5 × 6ᶜ (3,600)	93
[C] – Irapuato	3,250	"	189	1,730	"	100	3,440	"	159	1,820	"	126	7,790	"	180	3,750	"	104
Irapuato – Silao	2,500	"	145	1,210	"	70	2,690	"	125	1,300	"	90	7,740	"	179	3,630	"	101
Silao – [D]	3,800	4.4 × 6ᶜ (3,168)	120	1,820	3.4 × 6ᶜ (2,448)	74	3,890	5 × 6ᶜ (3,600)	108	1,860	3 × 6ᶜ (2,160)	86	10,320	8 × 6ᶜ (5,760)	179	4,810	7 × 6ᶜ (5,040)	95
[D] – [E]	3,870	"	123	1,850	"	75	3,960	"	110	1,890	"	87	10,450	"	181	4,860	"	96
[E] – Leon	5,250	"	167	2,310	"	94	5,340	"	148	2,350	"	109	11,870	"	206	5,230	"	104
Leon – [F]	150	"	5	70	"	3	150	"	42	70	"	3	380	"	7	170	"	3
[F] – Rincon	20	2.4 × 6ᶜ (1,728)	1	10	1.6 × 6ᶜ (1,152)	1	20	3 × 6ᶜ (2,160)	1	10	2 × 6ᶜ (1,440)	1	40	2 × 6ᶜ (1,440)	1	20	2 × 6ᶜ (1,440)	1

6-3 Rolling Stock Plan

6-3-1 Required quantity of rolling stock

The required quantity of rolling stock is determined by preparing the rolling stock rotation diagram, based on the train operation diagram described in the preceding section.

The quantity of spare rolling stock is determined by taking into consideration the rolling stock required for periodic inspection and emergency repair.

The quantity of rolling stock required by year is shown in the Table 6-3-1. (Rolling stock rotation diagram: Refer to Appendix 6-6.)

Table 6-3-1 Quantity of Rolling Stock Required by Year (c: cars)

		Case 1			Case 2			Case 3		
		In use	Spare	Total	In use	Spare	Total	In use	Spare	Total
1990	Stage 1	$3^c \times 10 = 30^c$	$3^c \times 3 = 9^c$	$3^c \times 13 = 39^c$	$3^c \times 10 = 30^c$	$3^c \times 3 = 9^c$	$3^c \times 13 = 39^c$	-	-	-
1995	Stage 1	3 × 10 = 30	3 × 3 = 9	3 × 13 = 39	3 × 10 = 30	3 × 3 = 9	3 × 13 = 39	-	-	-
	Stage 2	3 × 16 = 48	3 × 4 = 12	3 × 20 = 60	3 × 15 = 45	3 × 4 = 12	3 × 19 = 57	3 × 16 = 48	3 × 4 = 12	3 × 20 = 60
2000	Stage 2	6 × 16 = 96	6 × 4 = 24	6 × 20 = 120	6 × 15 = 90	6 × 4 = 24	6 × 19 = 114	6 × 16 = 96	6 × 4 = 24	6 × 20 = 120
	Stage 3	6 × 16 = 96	6 × 4 = 24	6 × 20 = 120	6 × 15 = 90	6 × 4 = 24	6 × 19 = 114	6 × 16 = 96	6 × 4 = 24	6 × 20 = 120
2010	Stage 3	6 × 23 = 138	6 × 4 = 24	6 × 27 = 162	6 × 20 = 120	6 × 4 = 24	6 × 24 = 144	6 × 23 = 138	6 × 4 = 24	6 × 27 = 162

6-3-2 Train make-up

During initial operation, the trains will have a three-car make-up, with subsequent expansion to a six-car make-up, as described in 6-2-2. The following train make-up is recommended in this project.

- 3 car make-up: Mc M' Tc
- 6 car make-up: Mc M' T M M' Tc

6-3-3 Specifications of the rolling stock

(1) Rolling stock gauge

The "Shinkansen (express) Standard" of the J.N.R. could be adopted in this case, the rail gauge being 1,435 mm, but the "Conventional Line Standard" of the J.N.R. is adopted instead, thorough consideration of the evolution of the traffic volume and the investments in rolling stock. (Rolling stock gauge: Refer to Appendix 6-8.)

(2) Specifications of the rolling stock

The specifications of the rolling stock are shown in Appendix 6-9.

6-3-4 Maintenance of the rolling stock

(1) Inspection system

The rolling stock is subject to problems such as wear, deterioration, and corrosion proportional to its running mileage and, as a consequence, its performance deteriorates gradually.

It is necessary, therefore, to inspect and repair the rolling stock at regular specified periods of time or distance, in order to maintain its satisfactory performance.

The type, contents, and period of inspection and repair are established as in Table 6-3-2, based on many years of experience of the J.N.R.

Table 6-3-2 Type, Cycle, Contents, and Site of Inspection

Type and Contents of Inspection			Inspection Cycle		Inspection Site
Type		Contents	Cycle	Running Distance	
Regular inspections	Overall inspection	The various parts of the rolling stock shall be disassembled and submitted to a detailed overall inspection.	Within 4 years	Within 800,000 km	Workshop
	Important components and parts inspection	The principal parts and components of the rolling stock, such as main motor, bogie, running gear, pantograph, auxiliary rotary machines, and ATS equipment, shall be removed or disassembled and inspected in detail.	Within 2 years	Within 400,000 km	Workshop
	Annual inspection (Truck inspection)	The main motor, truck, running equipment, and brake equipment shall be disassembled and inspected in detail.	Within 1 year	Within 200,000 km	Car depot
	Bimonthly inspection	The conditions, operation, and functions of the pantograph, special high-voltage circuit, rotary machine switches, brake equipment, bogie, running gear, and ATS equipment, shall be inspected in their normal conditions in the rolling stock.	Within 2 months	Within 30,000 km	Car depot
Daily inspection		Replacement and replenishment of wearing parts and external inspection of the state and operation of the pantograph, door opening/closing equipment, indoor equipment, truck, running gear.	Within 48 hours	—	Car depot
Temporary inspection		Inspection to be carried out as occasion demands, in the case of any trouble in the equipment.	Any time	—	Car depot or workshop

(2) Volume of inspection work

The inspection cycle is the basis for calculating the quantity of rolling stock to be inspected. There are two criteria to determine the inspection cycle of the rolling stock, i.e., the running distance (kilometers) and the number of days elapsed (number of days), according to the state of use of the rolling stock. In this project, the inspection cycle is determined in terms of running distance (kilometers) with the purpose of maximizing the efficiency of use and minimizing the required quantity of rolling stock.

The required volume of inspection work and the scale of the inspection and repair facilities are calculated as follows.

a. In the car depot (annual inspection and bimonthly inspection)

$$A = \frac{NK}{S} \times \beta \times \gamma \times D$$

Where,

A: Scale of the inspection and repair track (quantity of rolling stock)

N: Quantity of rolling stock (only motor cars in the case of annual inspection)

K: Average running kilometers per day

S: Inspection cycle in kilometers

D: Number of days required for inspection

β: Coefficient of coincidence with higher rank inspection

γ: Actual operation rate and fluctuation rate

Note 1: The number of days of operation, excluding Sundays, holidays and days for periodic inspection of machine, is normally 265 days per year.

Note 2: The fluctuation rate depends on the fluctuations of the traffic volume and inspection, but in this case it is assumed to be 20 percent (1.20).

b. Workshop (overall inspection and important components and parts inspection)

$$W = \frac{365 \times N \times K}{S} \times \beta$$

$$M = \frac{W \times D}{Y}$$

Where,

W: Number of rolling stock inspected per year

N: Number of rolling stock

K: Average running kilometers per day

S: Inspection cycle in kilometers

β: Coefficient of superposition with higher rank inspection

M: Quantity of rolling stock inspected per day

D: Number of days spent in the workshop (20 days in the case of inspection of important components and parts and 25 days in the case of overall inspection)

Y: Number of operation days (assumed to be 265 days)

The quantity of rolling stock to be inspected each year in the car depot and in the workshop and other relevant data is calculated for the sake of reference. (Refer to Appendixes 6-10 and 6-11.)

RAILWAY FACILITIES
CHAPTER 7

CHAPTER 7 RAILWAY FACILITIES

7-1 Topography and Geology

7-1-1 Topography

The area this railway is being planned for belongs to the central plateau of the country, which has a flat topography and altitudes in the region of 1,710 to 1,820 meters. On this plateau, at the northeast of Leon there are steep mountains consisting of acid eruptive rocks with altitudes of about 2,900 meters. On the other hand, at the north side of the plateau existing between Silao and Celaya there is a hilly country consisting of conglomerates, sandstone, and acid eruptive rock with altitudes in the order of 2,100 meters.

To the south of the plateau, the area between Salamanca and Celaya has hilly country with gentle slopes, consisting of acid eruptive rocks. In the area between Salamanca and San Francisco del Rincon there are hilly sections consisting of conglomerates and sandstone in the form of islands.

The principal rivers of this area are the Rio Laja, approximately 80 meters wide, which extends from east of Celaya to east of Salamanca; the Rio Lerma, approximately 80 meters wide, which is located near Salamanca; the Rio Guanajuato, approximately 32 meters wide, located near Irapuato; the Rio Silao, approximately 30 meters wide, located near Silao; and the Rio Santiago, approximately 15 meters wide, located near San Francisco del Rincon. In addition to the aforementioned rivers, there are many other irrigation canals, the largest one approximately 15 meters wide. In the dry season, there is no water in most of the rivers and canals of this area, with exception of part of the rivers and some canals that utilize well water. According to data and information collected on the field survey, the last inundation of the Rio Laja occurred in 1978.

7-1-2 Geology

With exception of some parts, most of the area where this railway is being planned is located on an alluvium deposit, with alternating sand and clay layers. The thickness of these layers is of the order of 20 to 30 meters. The N-value is of the order of 10 to 20 for depths up to 3 meters from the surface and 20 or more for larger depths, because the area in question consists of sandy cohesive soil with a high grade of consolidation. Generally, the foundation ground is expected to have sufficient bearing capacity to support structures when the N-value is 20 or more in the case of cohesive soil and 30 or more in the case of sandy layers. Therefore, the structures of this project can be constructed with spread foundation on the cohesive soil with N-value equal to or larger than 20.

The possibility of an earthquake in the Salamanca area is almost zero, according to the "Regionalizacion Sismica de Mexico para fines de Ingenieria" (Seismical Regionalization of Mexico for Engineering Purposes).

7-2 Construction Standards

7-2-1 General standards

The general standards for construction of railway tracks are shown in Table 7-2-1.

Table 7-2-1 General Standards

Item	Specification
Track gauge	1,435 mm
Distance between track centers	4,000 mm
Minimum curve radius	1,000 m
Maximum grade	1.5 %

7-2-2 Construction gauge

The construction gauges of this railway project, existing railways and highways of Mexico are shown in the Figs. 7-2-1 to 7-2-4.

(1) New railway construction gauge

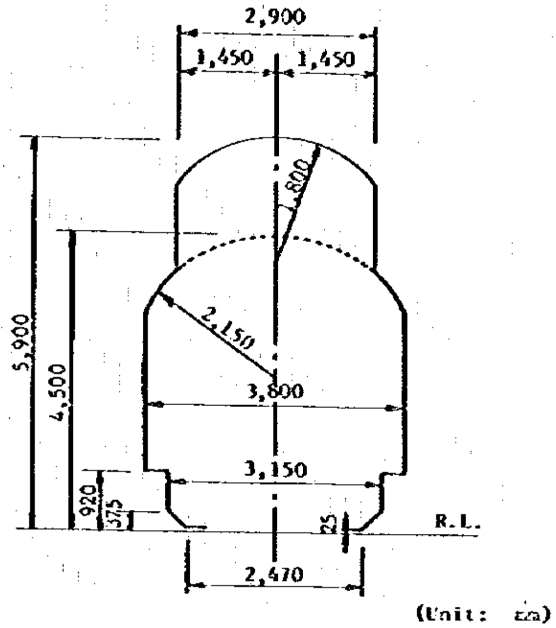


Fig. 7-2-1 New Railway Construction Gauge

(2) Existing railway construction gauge

The construction gauge of the National Railways of Mexico is as follows.

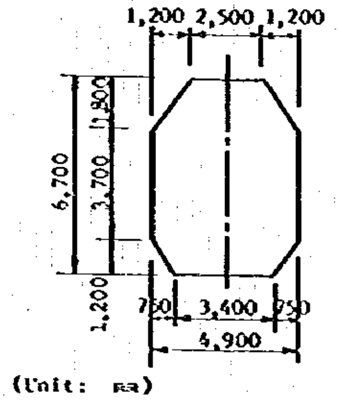


Fig. 7-2-2 Single Track

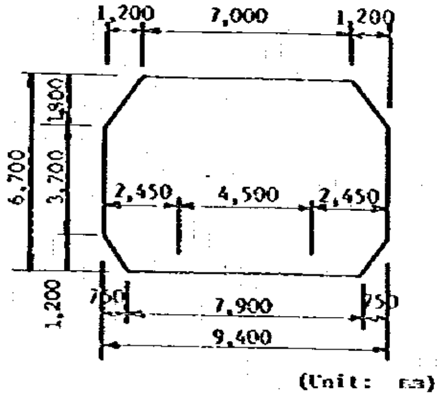


Fig. 7-2-3 Double Track

(3) Minimum construction gauge of highways

According to the SAHOP, the minimum construction gauge of highways is as follows.

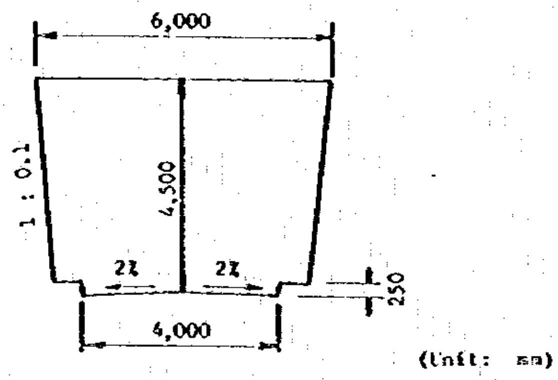


Fig. 7-2-4 Minimum Construction Gauge of Highways

7-2-3 Design live load

The design live load is planned to be the hauling load of Fig. 7-2-5. The axle load, P, is planned to be 14 tons.

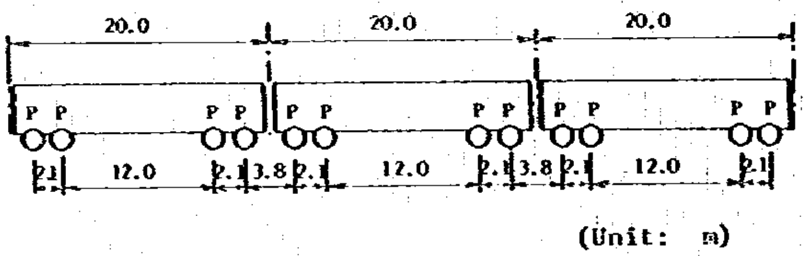


Fig. 7-2-5 Design Live Load

7-3 Structure Plan

7-3-1 Track structure and track formation level width

(1) Track structure

The specifications of the track structure are shown in the Table 7-3-1.

Table 7-3-1 Track Structure

Item	Contents
Rail	Equivalent to 50 kg/m
Sleeper	Prestressed concrete; 44 unit/25 meters
Ballast	250 mm thick

(2) Width of formation

The width of formation level is shown in the Figs. 7-3-1 and 7-3-2.

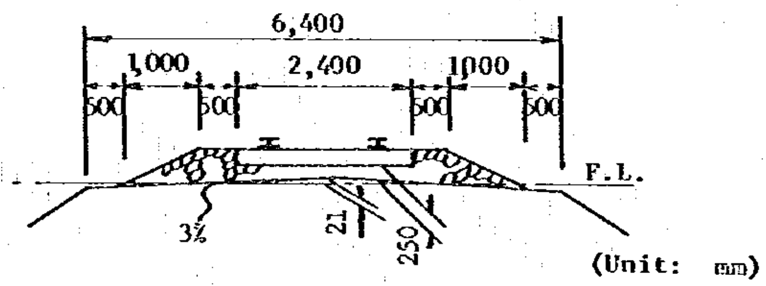


Fig. 7-3-1 Single Track

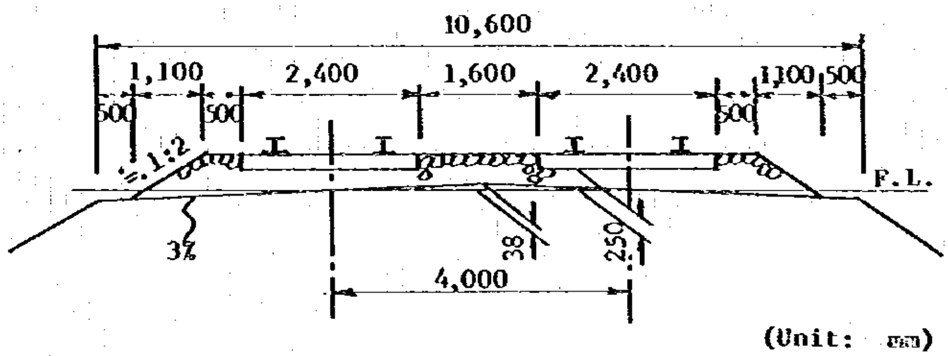


Fig. 7-3-2 Double Track

7-3-2 Earthwork

(1) Embankments

In principle, the embankments of this project should be low-type ones with heights in the order of 1 meter. The steepness of slopes should be 1:1.5 for embankment heights up to 12 meters and 1:1.8 for those exceeding 12 meters.

Berms should be provided for embankments exceeding 6 meters. The first berm should be located 3 meters below the top of the embankment and the subsequent ones should be separated by 6 meters. The width of the berm should be 1.5 meters.

The embankments constructed in this project should have the standard specifications described above.

(2) Cut

The standard steepness of slopes of the cuts should be 1:1. For rock, the steepness of slopes of the cuts should be 1:0.5.
The berms of the cuts should be the same as in the case of the embankments.

7-3-3 Structures

(1) River bridges

The bridges constructed across rivers should be simple beam types of reinforced concrete, with a span of approximately 20 meters, in view of economy and ease of maintenance.

(2) Viaducts of grade-separated crossings

Grade-separated crossings should be adopted at the intersections with the existing railways and the principal highways. The viaducts constructed in the grade-separated crossings should be simple beam types with a span of approximately 20 meters, in view of economy and ease of maintenance. The structure of these viaducts should be adequate for the width of the highways as they stand at the present time and the railway track width.

(3) Viaducts of urban areas

At stations, the viaducts should be rigid-frame, reinforced concrete structures able to contain the station building. At the other parts of the station section, the viaducts should be simple beam types, reinforced concrete, with a span of approximately 20 meters.

(4) Culverts

Irrigation canals cut by embankments should be provided with culverts. Box-type culverts should be used in the principal irrigation canals, while conventional pipe-type culverts on the market should be used in the minor irrigation canals.

The list of the structures is shown in the Table 7-3-2 and in Fig. 7-3-3.

Table 7-3-2 List of Structure Quantity

Classification	Quantity		Remarks
	No.	Length (km)	
Bank		153.5	
Cut		4.1	
Bridge	11	0.4	Reinforced concrete
Viaduct	5	9.0	Reinforced concrete
Box culvert	34		Reinforced concrete
Pipe culvert	512		Reinforced concrete

(Unit: mm)

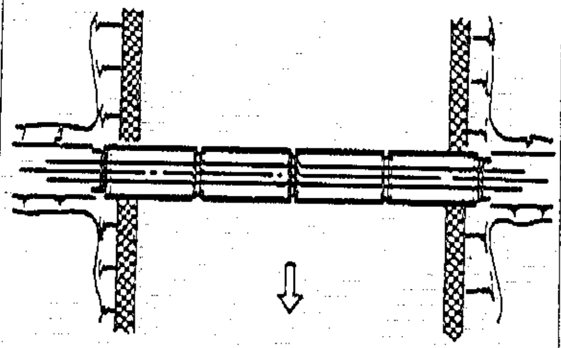
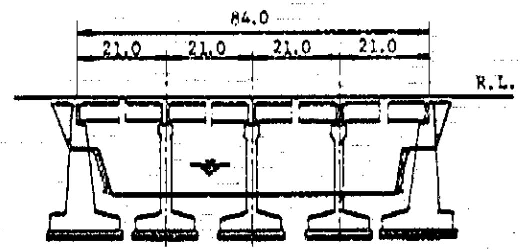
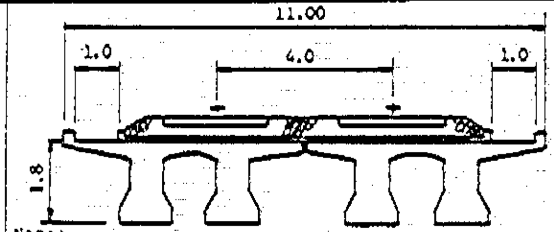
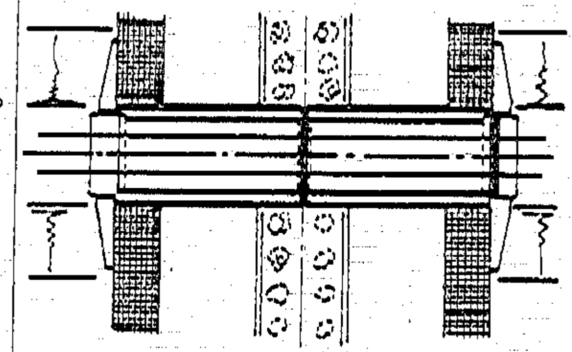
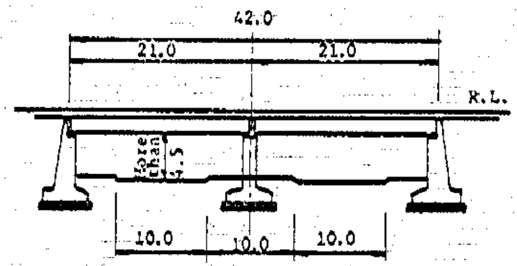
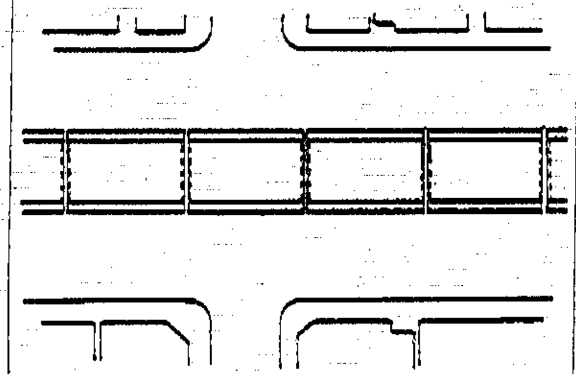
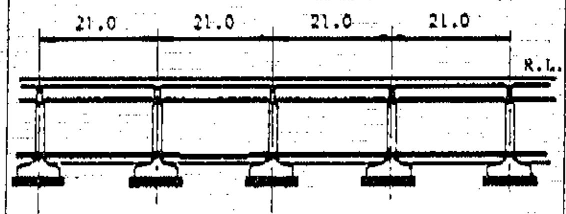
	Plane	Side view	Cross section
River bridges			 Note: • Includes girders less than 21 meters between piers.
Elevated crossing		 Note: In the case of an elevated crossing with a conventional railway a height of at least 6.70 meters is required under the girder.	• Same as above cross section. Note: • Includes girders 21 meters or less between piers. • Overpass intersection for roads or conventional railways.
Elevated bridges			• Same as above cross section. Note: • Includes girders 21 meters or less between piers.

Fig. 7-3-3 Structural Planning List (7)

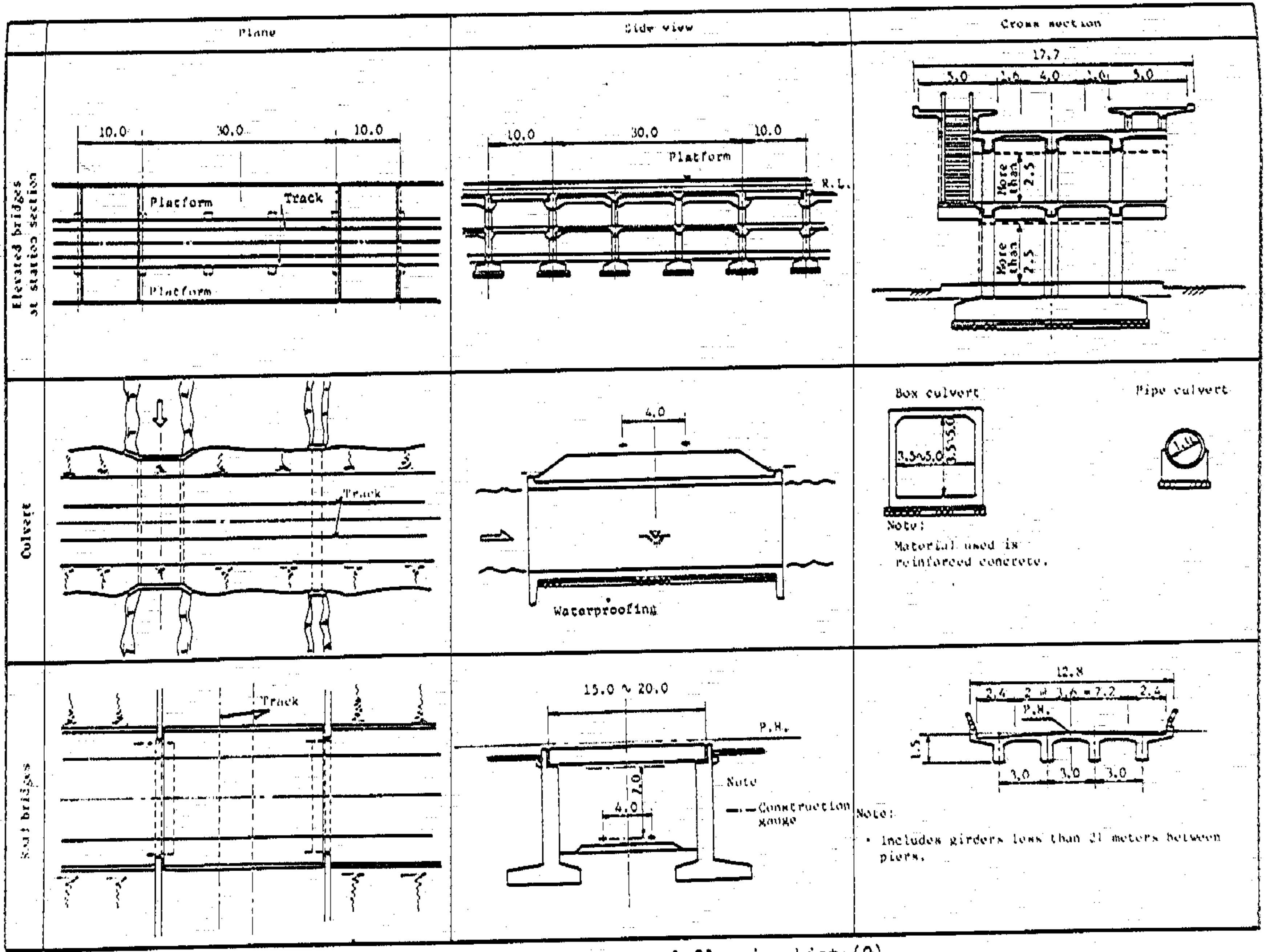


Fig. 7-3-3 Structural Planning List (2)

7-4 Station Facilities Plan

7-4-1 Track layout plan

The track layout of each station should be as follows.

(1) In Stage 1 of Case 1 and Case 2 (Fig. 7-4-1) and Stage 2 of Case 1, Case 2, and Case 3 (Fig. 7-4-2) the tracks should be arranged in such a way as to facilitate the works for construction of additional tracks for double-track configuration (Fig. 7-4-3).

(2) Safety sidings should be provided in the railway stations and signal stations of single-track sections; in order to ensure safety, trains should arrive simultaneously.

(3) Signal stations should be abolished with double-track operation.

(4) The through-type track layout without relief tracks should be adopted in the intermediate stations for double-track operation. However, connecting tracks should be provided to provide for maintenance work and emergencies.

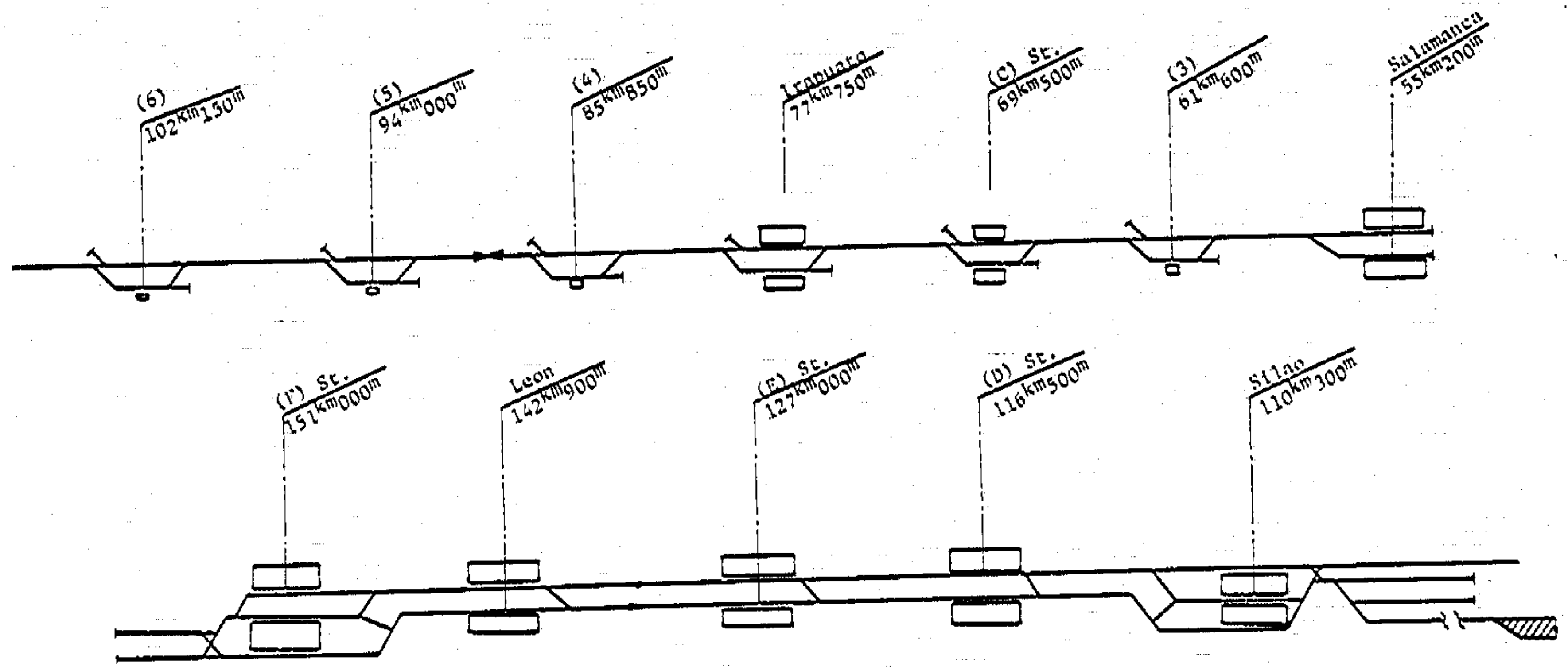


Fig. 7-4-1 General Layout of Track (Case 1 and Case 2, Stage 1)

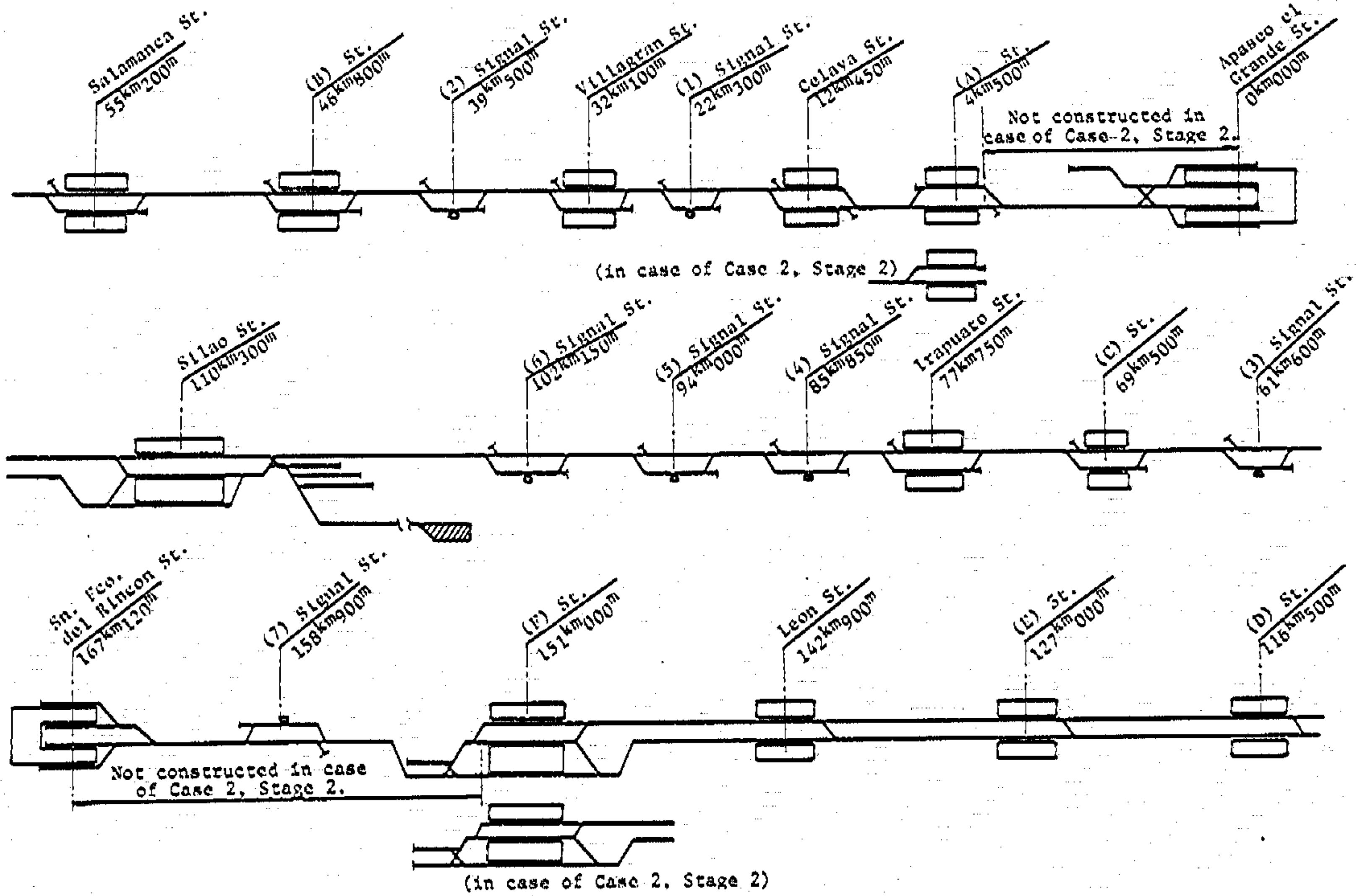


Fig. 7-4-2 General Layout of Track (Case 1 and Case 3, Stage 2)

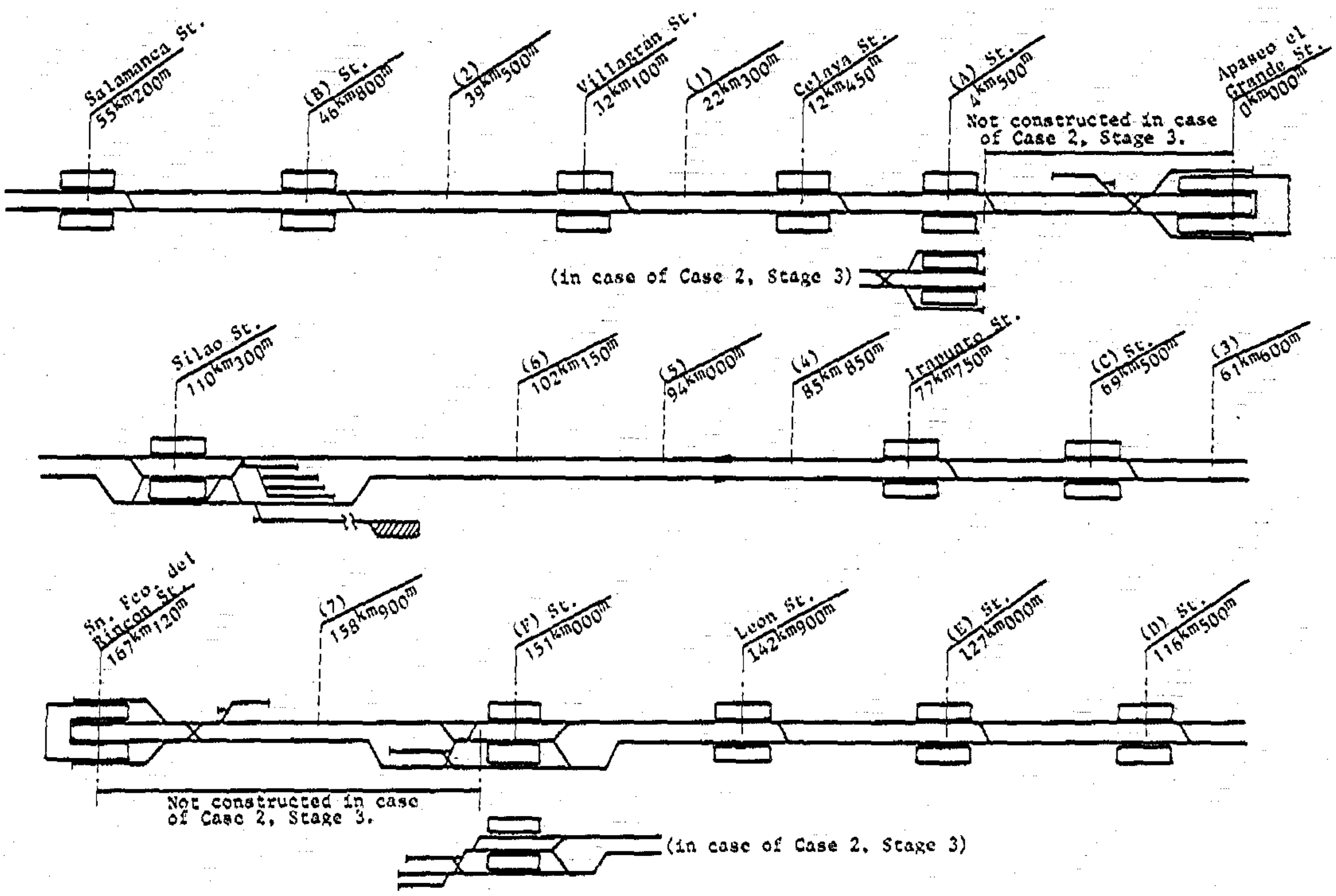


Fig. 7-4-3 General Layout of Track (Case 1 and Case 3, Stage 3)

7-4-2 Passenger service facilities

(1) Station main building

Generally speaking, the station main building shall consist of 4 principal facilities, in order to handle the traffic of the passengers in an efficient way.

Traffic facilities:	Station concourse and ticket gate
Passenger facilities:	Waiting room, washroom, parcel room, news stand, and telephone booths
Station service facilities:	Ticket office, and information bureau
Administrative facilities:	Station office and rooms for accessory facilities

The basic layout of the above facilities is shown in Fig. 7-4-4.

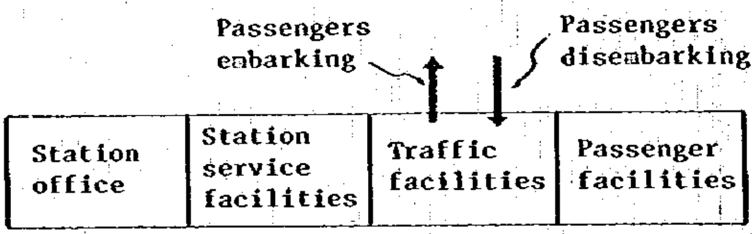


Fig. 7-4-4 Basic Layout of Station Facilities

The station main buildings are designed to two distinct scales, according to the characteristics of the passengers using them.

a) Stations principally handling commuters.
b) Stations principally handling ordinary.

The station main buildings of type a) are of a relatively small scale compared with buildings of type b), because they have a higher traffic efficiency.

Buildings of type a) should be constructed at stations A, B, C, D, E, and F. The scale of the station is calculated by using the calculation equation of the Japanese National Railways. (Table 7-4-1)

Table 7-4-1 Scale of Station Main Building

Scale of Station	Name of Station
3,400 m^2	Celaya, Salamanca, Irapuato, Silao, Leon
1,000 m^2	Villagran, C
500 m^2	Apaseo el Grande, A, B, D, E, F, Sn. Fco. del Rincon

In Celaya, Salamanca, and Leon, the station main building and the viaduct will be composed of a monoblock structure for the sake of more efficient utilization of the space under the viaduct.

(2) Passenger platform

The height of the passenger platform will be 920 mm above the top-of-rail level. The distance from the passenger platform front to the track center is 1,600 mm. The length of the passenger platform is 140 meters, by taking into consideration a sufficient margin to cope with 6-car trains.

The separate platforms are adopted in all stations of this project, considering train operation in the two terminal stations and the ease of future extensions in case transportation demand in the intermediate stations increases.

The width of the passenger platform is calculated from the number of passengers embarking and disembarking at the peak hour. (Table 7-4-2)

Table 7-4-2 Passenger Platform

Passenger Platform Width	Name of Station
3.0 m	Apaseo el Grande, A, Villagran, B, D, F, Sn. Fco. del Rincon
4.0 m	C, Silao, E
5.0 m	Celaya, Salamanca, Irapuato, Leon

(3) Passenger platform shed

The passenger platform shed should, in view of the passenger service requirements and weather conditions, be as follows. (Table 7-4-3)

Table 7-4-3 Passenger Platform Shed

Name of Station	Area Covered by the Shed
Celaya, Salamanca, Leon	Maximum train length
C, Irapuato, Silao, D, E, F	(Maximum train length) / 2
Apaseo el Grande, A, Villagran, B, Sn. Fco. del Rincon	2 cars

(4) Overbridge (for passengers)

Overbridges should be provided in all stations except terminal and overhead stations, for the assurance of passenger safety.

The overbridge should be arranged at a place where it does not cross with the traffic lines of the passengers. Furthermore, it should be at a convenient distance from the ticket gate in order to prevent congestion. (Fig. 7-4-5)

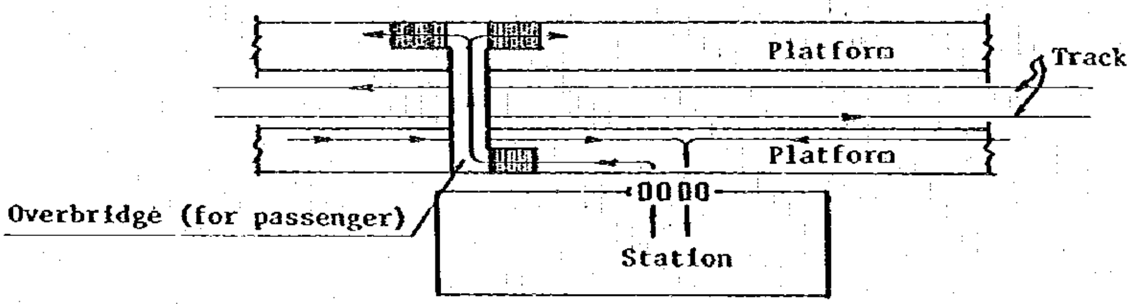


Fig. 7-4-5 Overbridge

(Refer to Appendix 7-1 for the station main building scale.)

7-5 Station Plaza Plan

7-5-1 Dimensions of the station plaza

The station plaza is the point of interconnection between the railway and other modes of transport. Therefore, it should be constructed to provide an organic interconnection between railway, cars, and pedestrians, by considering local peculiarities and the state of the transportation system.

The station plaza plays an important part as a subsidiary facility of the future railway system. Therefore, the standard dimensions of each station plaza is calculated based on the future transportation demand forecast (refer to Table 7-5-1).

The equation of the Japanese National Railways to calculate the dimensions of the station plaza is used in this study. The results of calculation are shown in Table 7-5-2.

Table 7-5-1 Arrivals and Departures of Railway Passengers for Each Station (Daily)

(Unit: Person)

Station	Passenger (A.D. 2000)
Apaseo el Grande	1,100
A	17,300
Celaya	43,400
Villagran	13,800
B	2,800
Salamanca	48,500
C	36,100
Irapuato	87,400
Silao	50,900
D	2,300
E	44,000
Leon	94,300
F	2,400
Sn. Fco. del Rincon	500

Table 7-5-2 Dimensions of Station Plaza at Each Station (A.D. 2000)

(Unit: m^2)

Station	Dimensions for Station Plaza
Apaseo el Grande	900 ∿ 1,000
A	1,500 ∿ 2,200
Celaya	9,800 ∿ 12,300
Villagran	4,100 ∿ 5,100
B	900 ∿ 1,000
Salamanca	10,400 ∿ 13,000
C	3,200 ∿ 4,600
Irapuato	13,900 ∿ 17,400
Silao	10,600 ∿ 13,300
D	900 ∿ 1,000
E	3,900 ∿ 5,600
Leon	14,500 ∿ 18,100
F	900 ∿ 1,000
Sn. Fco. del Rincon	900 ∿ 1,000

Note 1: Equation to calculate dimensions of station plaza (Station Plaza Research Committee)

A: Dimensions of station plaza
x: Daily passengers (arrivals and departures)

Station mainly for interurban passengers

$$8.99\sqrt{x} + 0.217x \leq A \leq 11.22\sqrt{x} + 0.271x \quad (\text{where } x \leq 30{,}000)$$

$$47.16\sqrt{x} \leq A \leq 58.90\sqrt{x} \quad (\text{where } x > 30{,}000)$$

Station mainly for commuters

$$0.0878x \leq A \leq 0.128x \quad (\text{where } x \leq 73{,}000)$$

Note 2: The area of the station plaza is calculated by assuming that stations A, B, C, D, E, and F are stations mainly for commuters, while the other ones are assumed to be stations mainly for interurban passengers. In some stations, the calculated dimensions are very small, making it difficult to assure the required functions. Therefore, 900 m^2 to 1,000 m^2 is adopted approximate standard dimension of these station plazas.

7-5-2 Required numbers of bus berths in the station plaza

The standard station plaza consists of bus berths, taxi berths, driveways, sidewalks, and landscape design space.

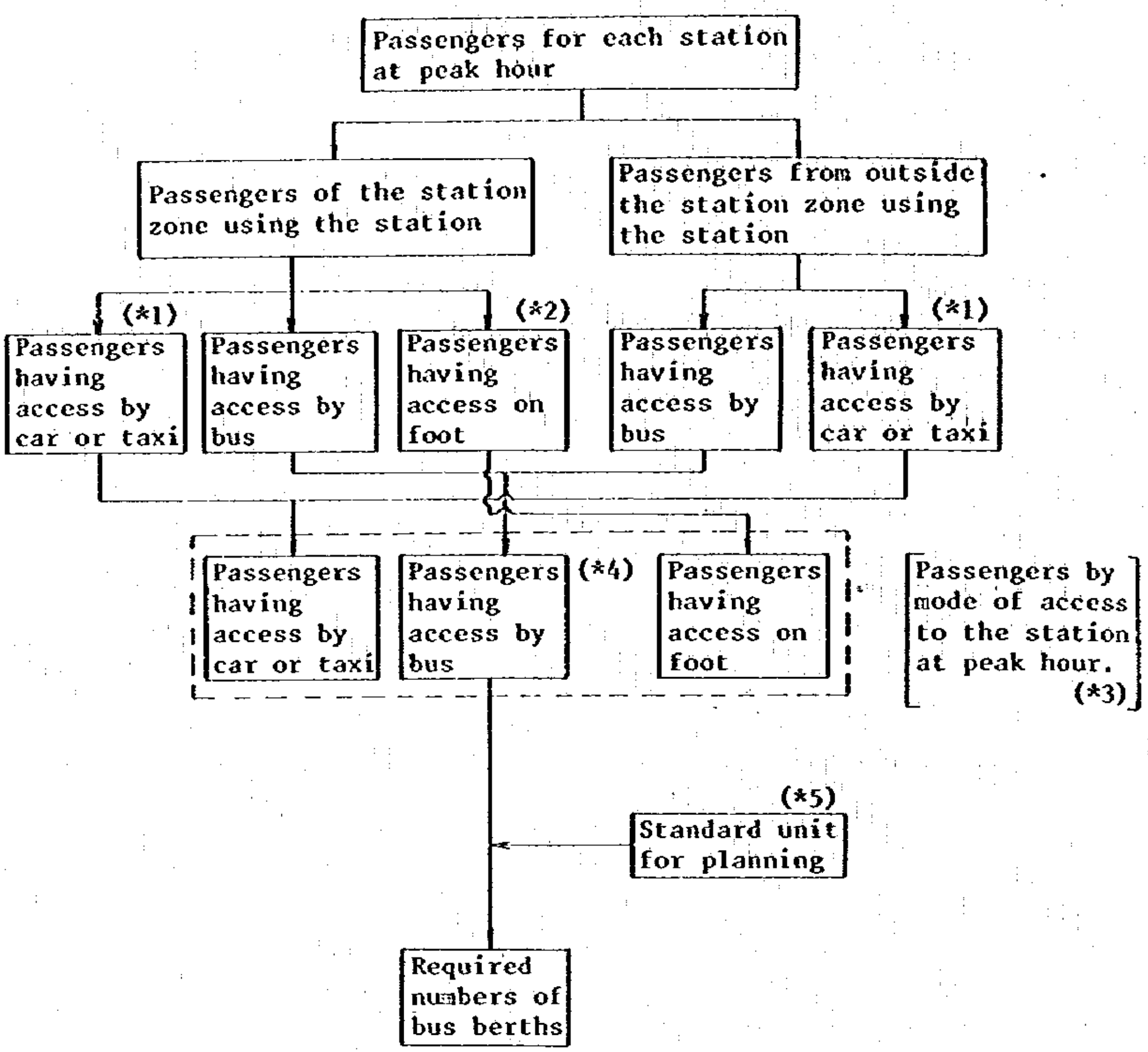
Each station plaza is planned by considering the space requirements of the above facilities, in addition to the peculiarities of each plaza. Since this report refers to the feasibility study of the project, it does not extend over the discussion of a plan of the station plaza. However, required numbers of bus berths is calculated by means of the flow chart of the next page (Fig. 7-5-1) and the results are used as reference data for planning and constructing the station plaza in the future.

The calculation results are shown in Table 7-5-4. The passenger traffic at peak hour, which is the basis of calculation, is shown in Table 7-5-3.

Table 7-5-3 Arrivals and Departures of Railway Passengers for Each Station (Peak Hour)

(Unit: Person)

Station	Passengers (A.D. 2000)
Apaseo el Grande	90
A	1,480
Celaya	3,710
Villagran	1,180
B	240
Salamanca	4,160
C	3,090
Irapuato	7,490
Silao	4,360
D	200
E	3,770
Leon	8,070
F	200
Sn. Fco. del Rincon	40



*1 Assuming 5% of passengers other than those having access to the station on foot.

*2 The distribution of railway passengers in the station zone is in principle assumed to be the same as the population distribution. It is assumed that 100% of the passengers within a radius of 900 m from the station and 50% of the passengers within 900 m to 1,500 m have access to the station on foot.

*3 The passengers having access by bicycle and motorcycle are neglected because their number is presumed to be extremely small.

*4 Buses are assumed to have access to the station plaza.

*5 40 passengers/bus
Loading berth : 12 buses/berth・hour
Unloading berth: 30 buses/berth・hour

Fig. 7-5-1 Flow Chart for Calculation of the Required Numbers of Bus Berths

Table 7-5-4 Required Numbers of Bus Berths (For Railway Passengers)

Station	Loading Berth	Unloading Berth
Apaseo el Grande	1*	
A	1	1
Celaya	3	2
Villagran	2	1
B	1*	
Salamanca	4	2
C	2	1
Irapuato	7	3
Silao	4	2
D	1*	
E	2	1
Leon	8	3
F	1*	
Sn. Fco. del Rincon	1*	

Note 1: The figures marked "*" indicate berths for both loading and unloading.

Note 2: The above figures refer only to the berths needed to serve railway passengers. Other users besides railway passengers, in particular the increase of users on special days (market days and public holidays), shall be considered in the actual plan of the station plaza.

7-6 Car Depot Construction Plan

7-6-1 Basic policy

The location of the car depot, which has a decisive influence on the operation and arrangement of the rolling stock and crew, is determined by the following considerations.

(1) Ease to cope with the various forms of transportation.

(2) Nearness to a place with a large discontinuity in the traffic volume, i.e., environs of terminal or turn-back point.

(3) Nearness to the station in order to minimize deadheading loss.

(4) Low construction cost

(5) The car depot shall be fully equipped with inspection and repair facilities.

7-6-2 Car depot facilities

The car depot should be located at a place with large discontinuity in the volume of traffic. The Silao station meets the above conditions so the car depot is located on its south side. There, required facilities can be arranged in a rational and organic way in the small available area.

The track layout of the car depot is arranged to enable smooth and efficient work. (Fig. 7-6-1)

The principal facilities of the car depot are shown in Table 7-6-1.

Table 7-6-1 List of Principal Facilities of the Silao Car Depot

Type of Facility	Track Name	Quantity	Remarks
Car storage and accommodation facilities	Accommodation track	8	To be constructed in various stages, according to the increase of the number of rolling stock
Inspection and repair facilities	Regular inspection track	1	Other tracks such as axle repair and washing tracks
	Daily and regular inspection track	1	
	Daily inspection track	1	
Workshop facilities	Departure and arrival inspection track	1	
	Car body lifting track	2	Car body repair shop
	Track repair, axle repair, and electrical parts repair shops		

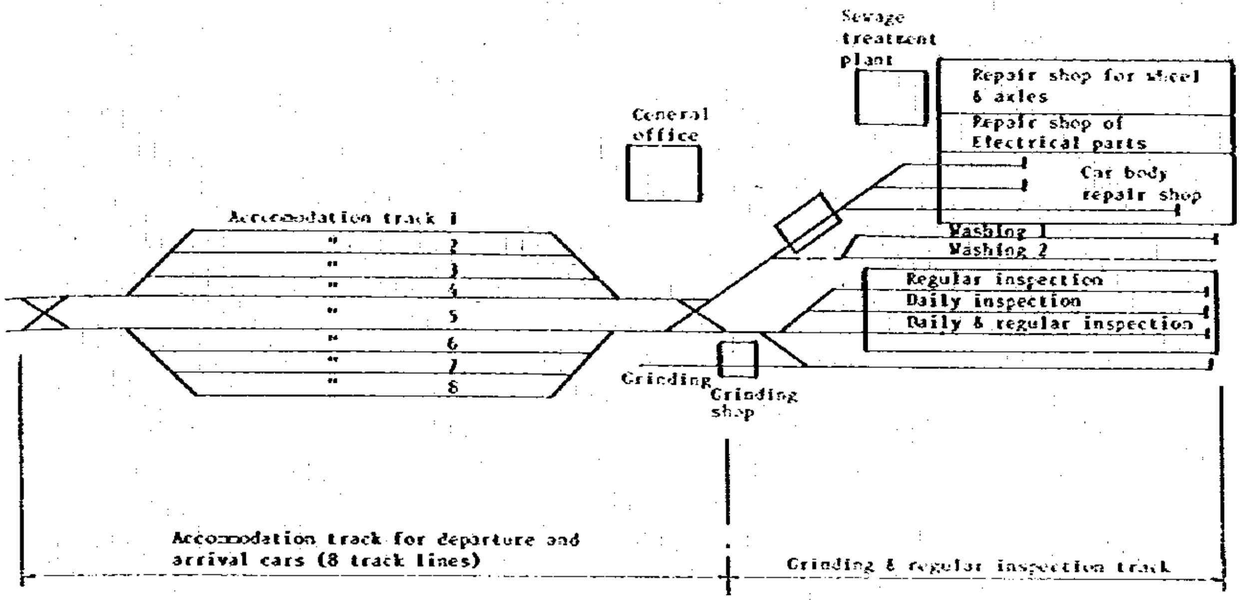


Fig. 7-6-1 Silao Car Depot Plan
(Final stage of each case)

7-7 Electrical System Plan

7-7-1 Electric power facilities

(1) Electrification plan

1) The single phase AC 60 Hz•AT (Autotransformer) feeding system is adopted in this study because it is more economical than the DC electrification system. Furthermore, it is the most economical AC electrification system for this project.

2) The feeding voltage is 25 KV, which is the international standard voltage.

(2) Power transmission network

The outline of the power transmission network of the C.F.E. (Comision Federal de Electricidad) along the new railway is shown in Fig. 7-7-1.

The power transmission network operates on three different voltages, 115 KV, 230 KV, and 400 KV.

The 115 KV power transmission network extends along the whole railway line. The 230 KV power transmission system is located in the section between the starting point and Leon. The 400 KV power transmission system is located in the section between the starting point and Salamanca. As the figure shows, this is a power source region.

(3) Substation facilities

The outline of the power source and feeding system is shown in Fig. 7-7-2.

1) The substation facilities consist of the substations, the sectioning post, and the AT posts.

2) The composition of the substation facilities is determined by the following.

   a) Transportation plan and load currents of trains

   b) Short-circuit capacity, unbalanced load ratio, and voltage regulation of the power transmission network of the C.F.E.

   c) Voltage drop of power source system and feeding system.

3) The receiving voltage at the substations is 115 KV.

4) The transformer capacity of the substation is SS_1 = 10 MVA and SS_2 = 15 MVA for main line feeding and SS_3 = 3 MVA for car depot.

5) The V-connection is adopted in the feeding transformers.

6) The substations and the sectioning post are designed for extended feeding.

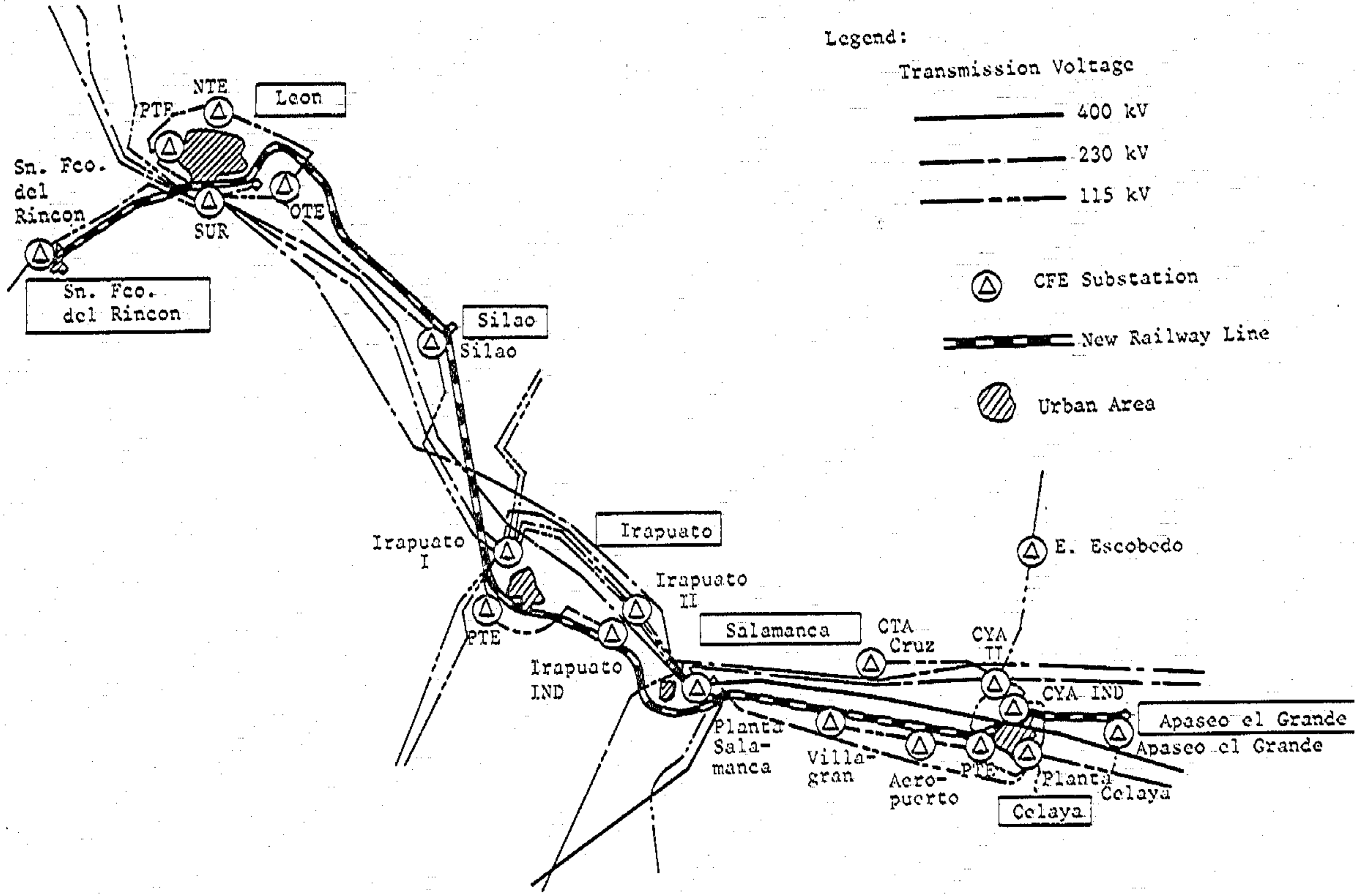


Fig. 7-7-1 Power Transmission Network in the Project Area

7) The sectioning post carries out the sectioning of the feeding from 2 substations. However, when one of the substations becomes unable to feed electric power, the substation in question and the sectioning post are switched to the extended system in order to feed power to the whole system. In this case, train operation is subject to some restrictions.

8) The substation facilities are unattended, monitored and controlled at the Leon control center.

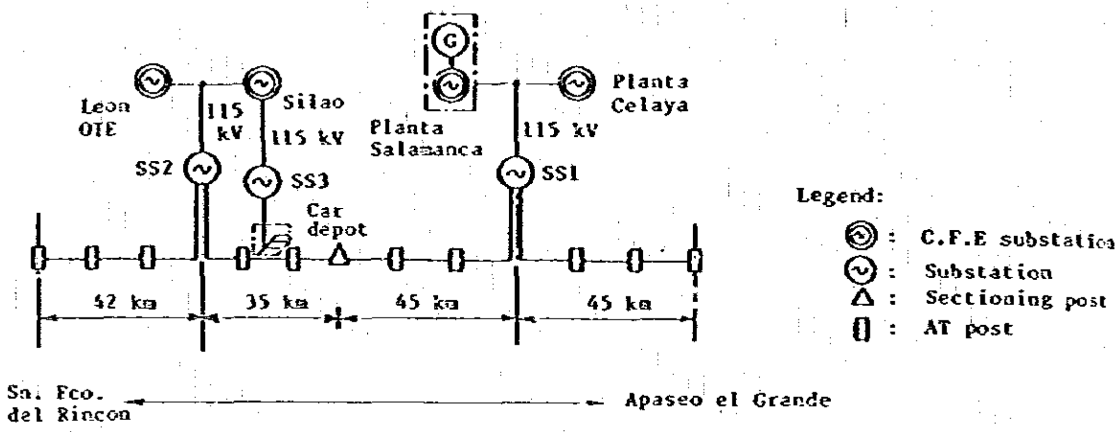


Fig. 7-7-2 Power Source and Feeding System

(4) Catenary system

The standard mounting of the catenary system between stations is shown in Fig. 7-7-3.

1) The heavy simple catenary system is adopted, by considering the planned maximum speed of 130 km/h. The messenger wire is a 135 mm^2 galvanized stranded steel wire and the contact wire is a 110 mm^2, grooved, hard copper wire.

2) Concrete poles are used to support the catenary system.

3) The catenary system is provided with an automatic tension balancer, in order to cope with temperature variations.

4) An overhead ground wire is provided to protect the feeder line and the high voltage distribution line for signals from lightning.

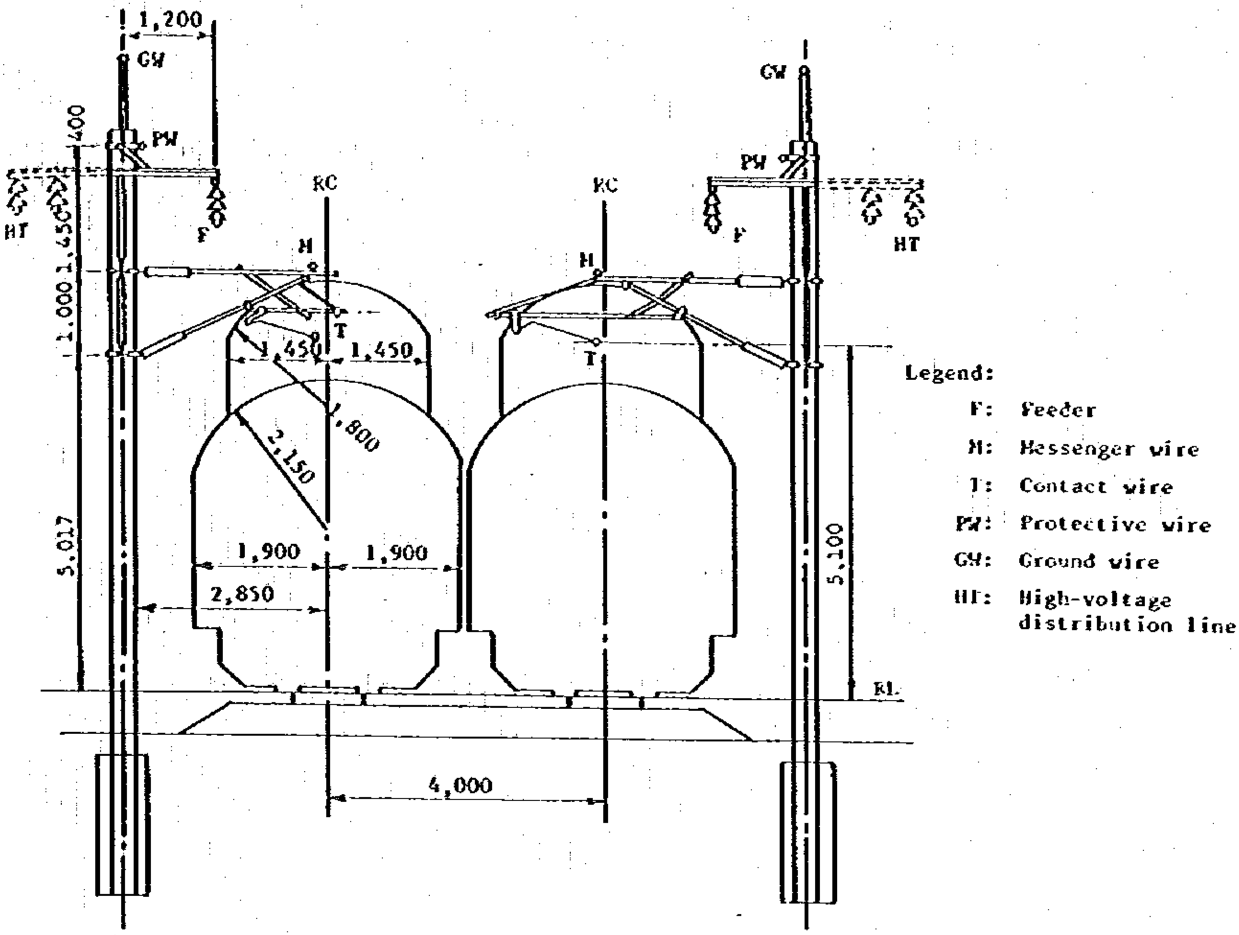


Fig. 7-7-3 Standard Mounting between Stations

(5) Lighting and power facilities

1) The C.F.E. distribution line supplies power to the lighting and power systems of the station buildings.

2) A high-voltage distribution line for signals is provided.

a) Distribution facilities are provided in the substations and the sectioning post.

b) The 13.8 KV the C.F.E. distribution line supplies power to the sectioning post.

c) The distribution line voltage is single-phase 13.8 KV.

d) The single-track sections are provided with one circuit, the double-track sections with two.

(6) Other requirements

This railway crosses or approaches the C.F.E. transmission lines at many places, as shown in Fig. 7-7-1. It is necessary to change the route or elevate the transmission lines that interfere with this railway. Therefore, it is necessary to carry out a careful study and to allow sufficient time for this work.

7-7-2 Signaling system

The composition of the signaling system is shown in Fig. 7-7-4.

(1) Block device

1) An automatic block system is provided in double-track sections, to assure the safety of train operation and shorten the running time.

2) The tokenless block system is provided in single-track sections to be converted to double track in future.

(2) Signal equipment

1) Color light type starting signals, home signals, and block signals are provided.

2) The shunting signals within station yards are position light types.

3) Route indicators are provided as required.

(3) Interlocking device

Relay interlocking devices are provided to assure train and yard operation safety and to improve the work efficiency.

(4) Switch machine

Electric switch machines are provided because they make possible a prompt switch and check of their performance and operation safety through electrically interlocking with the related signals.

(5) Track circuit

1) High-power DC track circuits are provided in the station yard.

2) 80 Hz AC coded track circuits are provided between the stations.

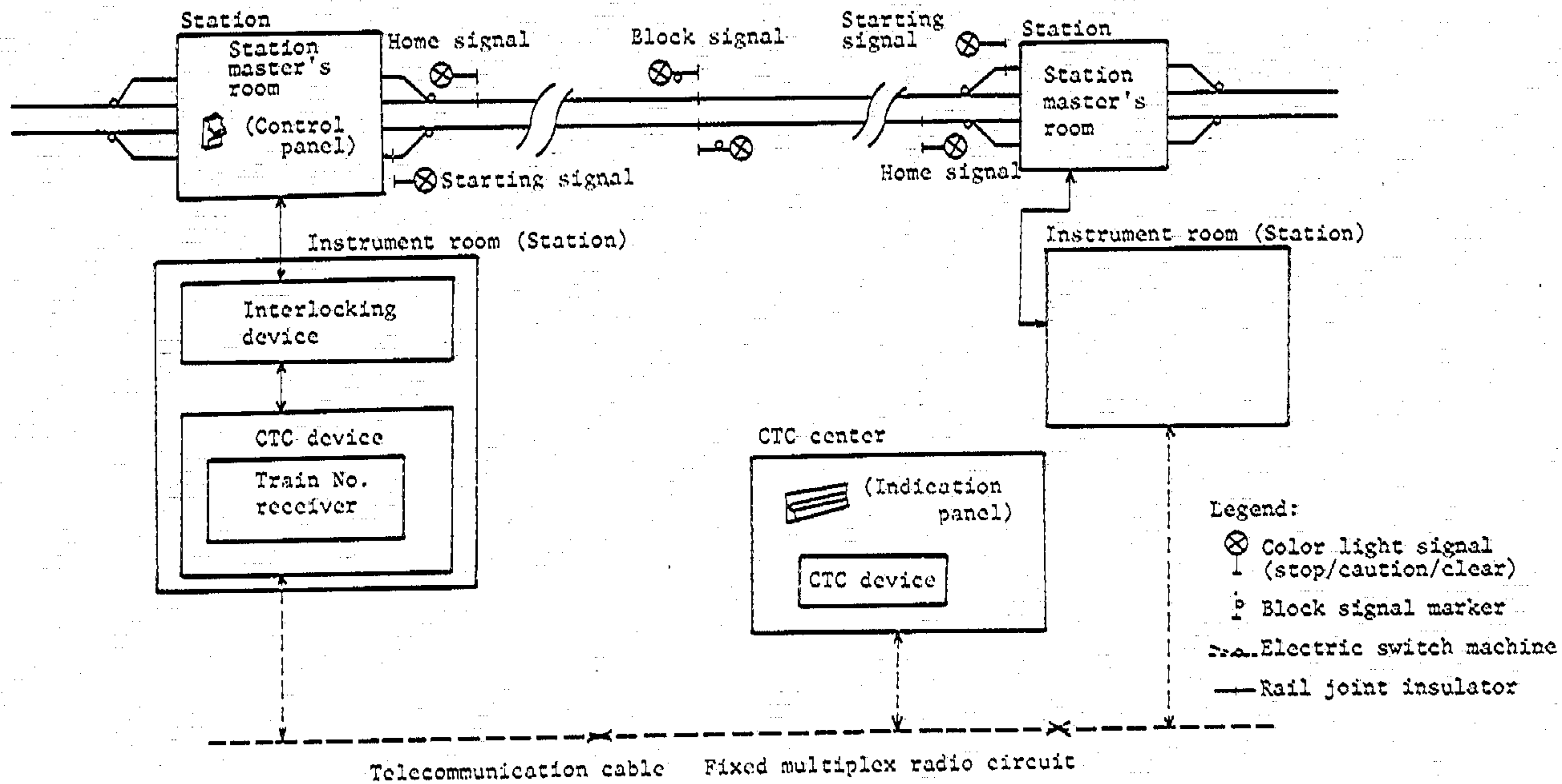


Fig. 7-7-4 Signaling System Composition

(6) Automatic Train Stop System (ATS)

Each signal is provided with ATS, which stops the train by automatically operating the brake if the train crew misinterprets or disregards the stop indication of signal.

(7) Centralized Traffic Control System (CTC)

1) The whole line is provided with CTC, which unifies the train dispatching operation, blocking operation, and train-route setting operation by centralized control through its network.

2) The central equipment is located in the Leon control center and local equipment is provided in each station.

(8) Grade crossing safety device

1) Ordinary crossings are provided with grade crossing signals that are controlled automatically according to the train movements. Grade crossing gates are added for grade crossings with large traffic volume.

2) Warning devices for train crews are provided, to cope with unexpected troubles (e.g. car trouble on the crossing).

(9) Cable lines

Multi-core corrugated cables are provided, in consideration of the concentration of equipment installation and inductive interference.

(Refer to Appendix 7-3 for the configuration of the signaling system for the whole railway lines.)

7-7-3 Telecommunication facilities

The telecommunication system is summarized in Fig. 7-7-5.

(1) Telecommunication system

1) Underground cable and radio equipment are provided for communication transmission and the CTC circuit has the duplicate system.

2) Dispatching telephone circuits of various kinds are provided to exchange information required to operate the trains.

3) Exclusive telephone circuits of various kinds are provided for train operation, maintenance of track systems, electric power systems, and signaling and telecommunication systems.

4) Loudspeaker telephone systems for passenger guidance are provided in each station and talk-back equipment is provided for communication between yardmen in main station yards.

5) The central office is located in Leon and automatic telephone exchanges are provided in its administrative office and also in the workshop and car depot at Silao.

6) Means to alleviate inductive disturbances in the telecommunications facilities along the railway are considered.

(2) Telephone system

1) Dispatching circuits for train operation, track maintenance, electric power, and signaling and telecommunication systems are provided between the dispatching center and each station, maintenance district, and substation.

2) Exclusive circuits for train operation, track maintenance, electric power, and signaling and telecommunication systems are provided between each station and between the dispatching center and each maintenance district.

(3) Facsimile system

The central facsimile equipment is installed at the dispatching center and receiver sets are provided at the main stations.

(4) Radio equipment

UHF radio stations are provided in all sections of the railway to compose telephone, CTC, substation control, and facsimile circuits together with the telecommunication cables.

(5) Telecommunication cable

Aluminum sheathed cables are provided in all sections of the railway because of its AC electrification system. These cables accommodate the various telecommunication circuits together with the radio equipment.

(See Appendix 7-4 for the composition diagram of the telecommunication system for the whole railway lines.)

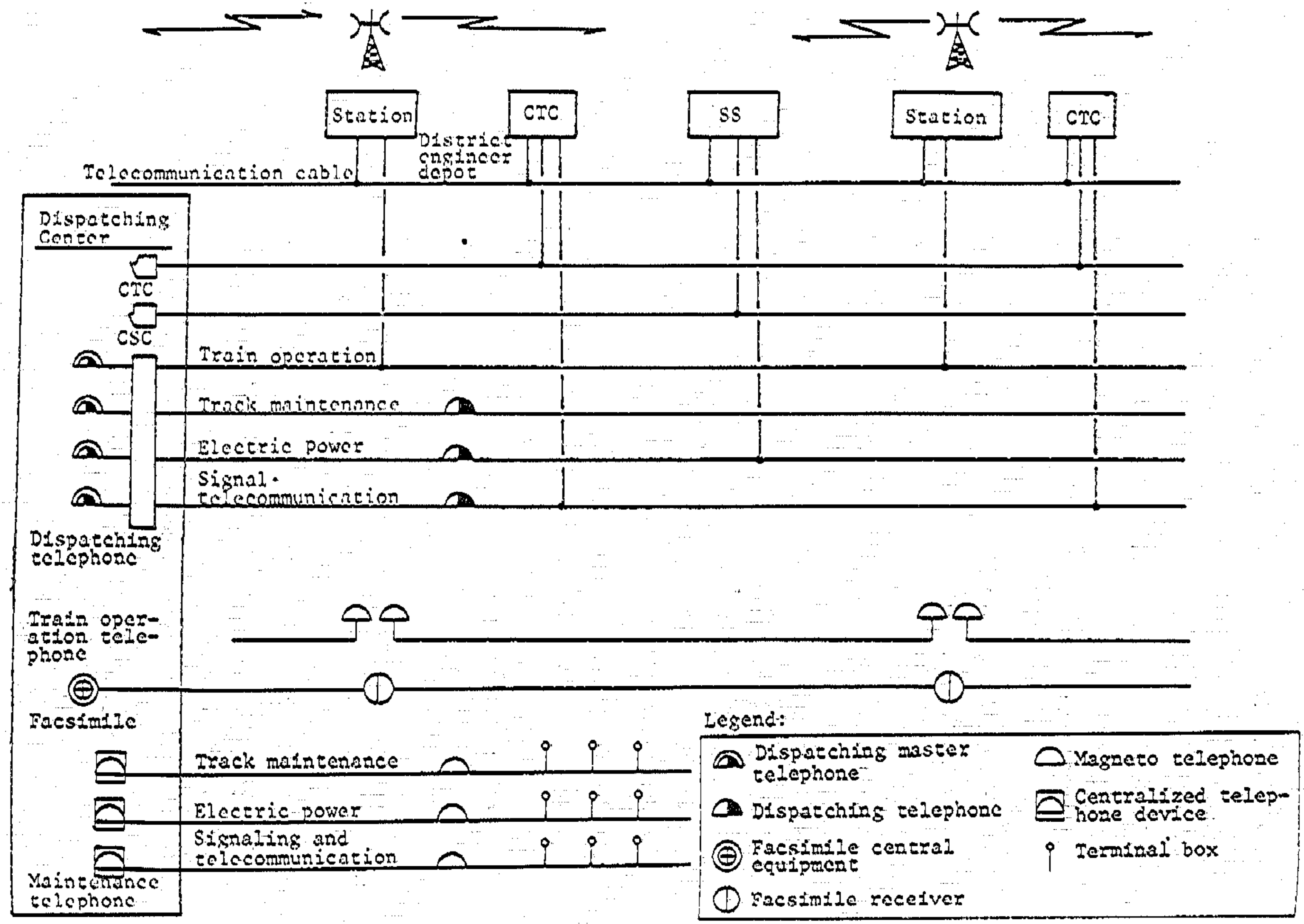


Fig. 7-7-5 Telecommunication System Composition

CONSTRUCTION SCHEDULE AND INVESTMENT SCALE

CHAPTER 8

CHAPTER 8 CONSTRUCTION SCHEDULE AND INVESTMENT SCALE

8-1 Construction Schedule

The construction schedule for each case is shown in Tables 8-1-1, 8-1-2, and 8-1-3.

8-2 Investment Scale

8-2-1 Preconditions for computing the construction cost

(1) The construction cost was computed as of April, 1983. Price increases have not been included.

(2) As much as possible, machines and materials to be used should be obtained in Mexico. However, all rolling stock and rails (excluding the turnouts, etc.), 70 percent of the electric equipment, and 40 percent of the inspection and repair machinery (at workshop) are assumed to be imported.

(3) The construction cost is divided into a domestic and foreign currency portion.

(4) Exchange rate: 1 US dollar = 111.95 Pesos (control rate)

8-2-2 Investment scale

Investment scales for each case are shown in Tables 8-2-1, 8-2-2, and 8-2-3.

Table 8-1-1 Case 1 Construction Schedule

Year / Activity	Stage 1						Stage 2					Stage 3				
	'84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
Surveying and design	—						—					—				
Land acquisition		—	—				—					—				
Civil engineering work		—	—	—	—	—		—	—	—	—		—	—	—	—
Station facility					—	—				—	—					
Car depot and workshop			—	—	—	—	—				—					
Track				—	—	—			—	—	—			—	—	—
Electrical work				—	—	—			—	—	—			—	—	—
Remarks	Salamanca - Silao - [F]						Apaseo el Grande - Salamanca [F] - Sn. Fco. del Rincon					Apaseo el Grande - Silao [F] - Sn. Fco. del Rincon				

Table 8-1-2 Case 2 Construction Schedule

Year / Activity	Stage 1						Stage 2					Stage 3				
	'84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
Surveying and design	—						—					—				
Land acquisition		—	—				—	—				—	—			
Civil engineering work		—	—	—	—			—	—	—	—		—	—	—	—
Station facility					—	—				—	—					
Car depot and workshop			—	—	—	—	—				—					
Track				—	—	—				—	—				—	—
Electrical work				—	—	—			—	—	—			—	—	—
Remarks	Salamanca - Silao - [F]						[A] - Salamanca					[A] - Silao				

Table 8-1-3 Case 3 Construction Schedule

Year / Activity	Stage 2											Stage 3				
	'84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
Surveying and design	—	—										—				
Land acquisition		—	—	—	—							—				
Civil engineering work			—	—	—	—	—	—	—	—			—	—	—	
Station facility									—	—	—					
Car depot and workshop								—	—	—	—					
Track							—	—	—	—				—	—	
Electrical work							—	—	—	—	—			—	—	—
Remarks	Apaseo el Grande – Silao – [F] – Sn. Fco. del Rincon											Apaseo el Grande – Silao [F] – Sn. Fco. del Rincon				

Table 8-2-1 Scale of Investment (Case 1)

(Unit: Million Pesos)

Activity \ Investment	Stage 1 1984 - 1989	Stage 2 1990 - 1994	Stage 3 1995 - 1999	Total Foreign Currency	Total Domestic Currency	Total Subtotal	Remarks
1. Civil engineering and track construction works							
Road bed	1,860	1,119	702	0	3,681	3,681	
Bridges	2,094	1,486	1,765	0	5,345	5.345	Including viaducts
Track	3,532	1,924	3,143	1,909	6,690	8,599	
Subtotal	7,486	4,529	5,610	1,909	15,716	17,625	
2. Electric power facilities							
Substation facilities	836	535	506	870	1,007	1,877	
Catenary facilities	998	520	927	1,197	1,248	2,445	
Lighting and power facilities	827	343	481	0	1,651	1,651	
Subtotal	2,661	1,398	1,914	2,067	3,906	5,973	
3. Signaling & Telecommunication work							
Signaling system	856	316	499	1,078	593	1,671	
Telecommunication system	1,000	889	0	1,307	582	1,889	
Subtotal	1,856	1,205	499	2,385	1,175	3,560	
4. Station facilities	602	220	0	0	822	822	Including passenger platforms, overhead bridges, passenger platform sheds, and management office
5. Car depot and workshop	2,449	909	0	1,048	2,310	3,358	Including land, track, buildings, and electrical facilities
6. Land and house compensation	893	362	88	0	1,343	1,343	
7. Rolling stock	4,878	2,628	6,310	10,447	3,369	13,816	
Total	20,825	11,251	14,421	17,856	28,641	46,497	

Table 8-2-2 Scale of Investment (Case 2)

(Unit: Million Pesos)

Activity \ Investment	Stage 1 1984 - 1989	Stage 2 1990 - 1994	Stage 3 1995 - 1999	Total: Foreign Currency	Total: Domestic Currency	Total: Subtotal	Remarks
1. Civil engineering and track construction works							
Road bed	1,860	779	584	0	3,223	3,223	
Bridges	2,094	1,467	1,743	0	5,304	5,304	Including viaducts
Track	3,532	1,427	2,637	1,689	5,907	7,596	
Subtotal	7,486	3,673	4,964	1,689	14,434	16,123	
2. Electric power facilities							
Substation facilities	836	514	485	852	983	1,835	
Catenary facilities	998	367	764	1,046	1,083	2,129	
Lighting and power facilities	827	242	399	0	1,468	1,468	
Subtotal	2,661	1,123	1,648	1,898	3,534	5,432	
3. Signaling & telecommunication work							
Signaling system	698	491	199	890	498	1,388	
Telecommunication system	1,147	651	0	1,246	552	1,798	
Subtotal	1,845	1,142	199	2,136	1,050	3,186	
4. Station facilities	591	181	0	0	772	772	Including passenger platforms, overhead bridges, passenger platform sheds, and management office
5. Car depot and workshop	2,449	909	0	1,048	2,310	3,358	Including land, track, buildings, and electrical facilities
6. Land and house compensation	893	264	62	0	1,219	1,219	
7. Rolling stock	4,878	2,252	5,995	9,925	3,200	13,125	
Total	20,803	9,546	12,868	16,696	26,519	43,215	

Table 8-2-3 Scale of Investment (Case 3)

(Unit: Million Pesos)

Investment / Activity	Stage 2	Stage 3	Total			Remarks
	1984 - 1994	1995 - 1999	Foreign Currency	Domestic Currency	Subtotal	
1. Civil engineering and track construction works						
Road bed	2,979	702	0	3,681	3,681	
Bridges	3,580	1,765	0	5,345	5,345	Including viaducts
Track	5,456	3,143	1,909	6,690	8,599	
Subtotal	12,015	5,610	1,909	15,716	17,625	
2. Electric power facilities						
Substation facilities	1,371	506	870	1,007	1,877	
Catenary facilities	1,518	927	1,197	1,248	2,445	
Lighting and power facilities	1,170	481	0	1,651	1,651	
Subtotal	4,059	1,914	2,067	3,906	5,973	
3. Signaling & telecommunication work						
Signaling system	1,172	499	1,078	593	1,671	
Telecommunication system	1,889	0	1,307	582	1,889	
Subtotal	3,061	499	2,385	1,175	3,560	
4. Station facilities	822	0	0	822	822	Including passenger platforms, overhead bridges, passenger platform sheds, and management office
5. Car depot and workshop	3,358	0	1,048	2,310	3,358	Including land, track, buildings, and electrical facilities
6. Land and house compensation	1,255	88	0	1,343	1,343	
7. Rolling stock	7,506	6,310	10,447	3,369	13,816	
Total	32,076	14,421	17,856	28,641	46,497	

ECONOMIC ANALYSIS
CHAPTER 9

CHAPTER 9 ECONOMIC ANALYSIS

9-1 Method of Economic Analysis

9-1-1 With/Without analysis

This analysis shall be conducted by comparing the case in which the project is implemented (With the Project) and the case in which the project is not implemented (Without the Project). In other words, the costs which would be incurred in the case of "Without the Project" shall be deemed to be saved by implementing the project and shall be deducted from the project cost. In a similar way, the benefits shall be computed for the two cases and the difference between them shall be determined. It follows that, unless the benefits in the case of "With the Project" are larger than those in the case of "Without the Project," then project implementation should be reconsidered.

In the case of "Without the Project," the future traffic demand would continue to be handled on highways. Generally, the costs include road expansion, road maintenance, investment in road vehicles and vehicle maintenance for the increasing traffic.

As for roads, however, there are already plans to expand the present four-lane (two-lane on each side) highway between Apaseo el Grande and Irapuato to six lanes and the present two-lane (one-lane on each side) highway between Irapuato and Leon to four lanes. These highways are expected to deal with the increasing traffic up to the year 1995 or 2000. Therefore, in this analysis, the costs for roads and bus-terminals necessary after the year 1995 have been estimated and counted as costs for "Without the Project." To be more specific, it is assumed that the traffic will be saturated by 1995 between Silao and Leon, and by 2000 between Irapuato and Silao, and that it will be necessary to construct additional road facilities by the above years in respective districts.

The number of road vehicles (buses) to be purchased was calculated by dividing the passenger kilometers (number of passengers × travelling distance) obtained from demand forecast by the mean number of passengers (25 persons) per bus, and then dividing this quotient (vehicle kilometers) by the annual mean travelling distance (70,000 km) per bus.

9-1-2 Alternatives for "With the Project"

The alternatives for "With the Project" are the three cases discussed earlier in Chapter 4 'Alternatives.' In this Report, those three cases are analyzed and compared. As was mentioned earlier, the route shall be fixed, and the motive power shall be electricity.

9-1-3 Evaluation indices

The differences in investments, maintenance and operation costs, and benefits shall be computed between "With the Project" and "Without the Project" for each year, and are seen as Net Flow. An Economic Internal Rate of Return (EIRR)* is calculated on this Net Flow to be used as one of the bases for the evaluation.

$$*: \quad 0 = \sum_{i=1}^{30} \text{Net Flow } i/(1 + \text{EIRR})^{i-1}$$

This index is an overall parameter which uses economic prices for evaluating the following items.

(1) Investment cost, operating cost, maintenance cost

(2) Land acquisition cost

(3) Benefits to railway users (time-savings)

9-1-4 Presuppositions

(1) Exchange rate

¥237.15 = 1.00 US Dollar = 148.65 Pesos (Rates as of April 29, 1983)

The Mexican Peso has two exchange rates, the controlled rate and the free rate. For imported goods, the former is applied. However, in an economic analysis, the prevailing rate is normally used, and thus the free rate has been used for all the prices in this analysis.

(2) Useful life and reinvestment

As maintenance rates and useful lives of railway assets are not available in Mexico, the figures used by Japanese National Railways have been applied. Details are shown in Table 9-1-1.

Table 9-1-1 Maintenance Rates and Useful Lives of Railway Assets

Items	Assets Description	Maintenance Rate	Useful Life	Type of Assets
Civil engineering work	Foundations	0.0004	57	Depreciable assets
	Elevated track structure	0.0027	50	"
	Platforms	0.0041	32	"
	Overbridges	0.0051	32	"
	Station buildings (RC)	0.0067	45	"
	Buildings (RC)	0.0057	45	"
	Tracks	0.15	25	Replaceable assets
Signals and telecommunication	Grade crossing safety equipment	0.0292	30	Depreciable assets
	Signal equipment	0.0210	20	"
	Telecommunication equipment	0.0312	20	"
	Signal lines	0.035	35	Replaceable assets
	Communication lines	0.12	35	"
	Track circuits	0.035	19	"
Electric equipment	Transformer equipment	0.0008	30	Depreciable assets
	Buildings for substations	0.0057	45	"
	Overhead contact wires	0.03	45	Replaceable assets
	Electrical distribution wires (light, electric power)	0.15	30	"
Rolling stock	Machinery at workshop	0.05	30	Depreciable assets
	Electric car	0.035	20	"
	Machinery at depot	0.05	30	"

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

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

(3) Inflation

Inflation was not considered for the following reasons.

1) It is impossible to forecast the rate of inflation over 30 years, and an incorrect forecast could substantially bias the economic evaluation.

2) Inflation will be correlated with investment, cost and benefits.

(4) Traffic volume to be diverted to the New Railway

It has been assumed as a result of the demand forecast discussed earlier, that the traffic will be diverted only from buses, which are now the only public transportation facility available.

(5) Pricing date

Prices as of April 1983, the investigation period, have been used in this study.

9-2 Economic Cost Estimation

9-2-1 Investment cost (Construction cost)

Economic costs have been estimated by adjusting the financial costs in the following manner.

(1) Tax adjustment

1) Foreign currency portion

Import duties and value added taxes (IVA; 15%) were excluded. Although these taxes are related to the foreign currency portion, they should be classified as domestic currency portion.

2) Domestic currency portion (Materials and equipment cost)

IVA were excluded. The construction cost naturally includes a certain amount of taxable profit for the contractors. However, since it is difficult to estimate the amount of profit for the contractors, corporate income taxes were not considered in this analysis.

3) Domestic currency portion (Labor cost)

It was assumed that the average monthly wage of the workers for this project would be approximately 18,000 Pesos. The personal income tax of 2 percent and IVA were excluded, with 1 percent of the personal income tax being the so-called one percent tax.

(2) Reinvestment and additional investment

It was assumed that reinvestment in the same amount shall be made for all the assets after the completion of the useful lives, as described in Table 9-1-1. This provides a common basis for both "With the Project" and "Without the Project" cases. As the station buildings, station plazas, platforms, electric cars, electric car depots, and electrical equipment are designed to cope with the traffic demand in the year 2000, they were assumed to be additionally invested in accordance with increases in traffic volume after the said year.

(3) Residual value

The project life of 30 years is for analysis only. The railway facilities will actually continue to operate beyond that time. Therefore, the residual values of assets have been counted as minus costs in the final year of the project life.

(4) Economic value of land

Instead of the actual acquisition cost (financial cost) the assessed value for taxation was used. As the assessed value is determined by the productivity of the land, it should reasonably reflect land value in terms of the national economy.

The economic investment costs estimated by the procedures so far mentioned are summarized in Table 9-2-1.

Table 9-2-1 Summary of Economic Values of Investment Cost

(Unit: Million Pesos)

	With/ Without	With Project			Without Project		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
Construction cost by stage	Stage 1 (1984∿1989)	19,240	19,228	2,974	0	0	0
	Stage 2 (1990∿1994)	11,200	9,658	26,691	4,327	4,327	1,782
	Stage 3 (1995∿1999)	14,207	12,744	14,982	5,161	4,667	7,706
	Additional investment (2000∿2013)	13,176	11,916	6,902	13,569	13,566	11,367
Construction cost by kind	Electric power facilities	6,333	5,817	6,333	0	0	0
	Signals and telecommunication	5,024	4,771	3,829	0	0	0
	Civil engineering work	17,548	16,127	17,548	3,478	3,040	3,478
	Land acquisition and compensation	885	813	885	623	570	623
	Electric cars	22,950	20,922	18,542	0	0	0
	Buses	3,687	3,700	3,016	18,956	18,950	16,754
	Machinery at the car depot	1,396	1,396	1,396	0	0	0
Total investment		57,823	53,546	51,549	23,057	22,560	20,855

Note: Figures include reinvestment of each item but exclude residual values.

9-2-2 Maintenance and operation cost difference

Maintenance and operation cost difference was calculated between "With the Project" and "Without the Project." The costs for "Without the Project" include maintenance and operation costs for only the buses. Private cars were not considered.

(1) Maintenance costs

The maintenance and replacement costs of railway assets were estimated using the method adopted by Japanese National Railways (Refer to Table 9-1-1 for maintenance cost ratio by assets).

The calculation method is as follows.

1) Maintenance cost of depreciable assets
= Maintenance ratio × original investment value of depreciable assets

2) Maintenance cost of replaceable assets
= (1.17 × 0.95/useful life) × maintenance ratio × total of replaceable assets

3) Replacement cost of replaceable assets
= (1.17 × 0.95/useful life) × total of replaceable assets

The maintenance costs of buses were based on the data supplied by Mexico. According to this data, the annual maintenance cost per bus (economic value) is approximately 1,114,000 Pesos (life — 20 years). (The market price was converted into the economic price by considering the estimated ratio between economic and market prices of the vehicle itself.)

The road maintenance costs were obtained by applying the maintenance ratio (0.008) as estimated by Japanese examples.

(2) Operation costs

Labor costs and motive power costs were calculated for both the railway and for buses. Details are shown in Table 9-2-2.

Table 9-2-2 Comparison of Operating Costs between the Railway and Buses

	Railway			Bus		
	Job Classification	Number of Employees	Average Annual Wage (Pesos)	Job Classification	Number of Employees	Average Annual Wage (Pesos)
Labor cost	Class A	*1	861,000	Driver	*2	770,000
	Class B		578,000	Conductor		368,000
	Class C		368,000	Others		476,000
Motive power cost	Electric power consumption per vehicle km		2.03 kwh	Diesel consumption per vehicle km		0.25 ℓ
	Economic cost of electric power per kwh		1.28 Pesos	Economic cost of 1 liter of diesel oil		*3 5.6 Pesos
	Economic cost of electric power per vehicle km		2.60 Pesos	Economic cost of diesel oil per vehicle km		1.4 Pesos

*1: Refer to Appendix for numbers of railway personnel.

*2: It was assumed that 1.8 drivers, 1.8 conductors and 1.0 other staff are needed per bus.

*3: Sixty percent of the cost was considered as tax and was excluded from the market price.

9-3 Benefits

The benefits to the public brought by this project were quantified as the difference between "With the Project" and "Without the Project." Specifically the time saved by passengers and the reduction in the transportation cost were considered. There will be other benefits in addition to these, such as increased comfort and convenience, and also the effects of urban development, etc., but since these are difficult to quantify, they were not counted.

9-3-1 Time saving benefit

Passengers who use the new railway instead of buses can enjoy a reduced travel time.

This time saving benefit by railway passengers can be obtained by the following equation.

$$\text{Savings} = \left(\begin{array}{l}\text{Total passenger-hours} \\ \text{per year in the case of} \\ \text{"Without the Project"}\end{array} - \begin{array}{l}\text{Total passenger-hours} \\ \text{per year in the case} \\ \text{of "With the Project"}\end{array}\right) \times \begin{array}{l}\text{Time value} \\ \text{of railway} \\ \text{passengers}\end{array}$$

Based on the earlier stated traffic demand forecast, passenger hours are obtained by multiplying the number of passengers of the railway or buses by the travelling time. However, the passenger-hours for "With the Project" include the time necessary for access transportation to the railway station and for transfers.

Table 9-3-1 Comparison of Passenger-hours

(Unit: Million/year)

Year \ Case	Without Project	With Project		
		Case 1	Case 2	Case 3
1990	56.5	56.6	56.6	
1995	94.9	91.6	91.7	91.6
2000	160.0	148.0	148.1	148.0
2010	331.5	309.0	309.1	309.0

The time value was estimated at 110 Pesos per hour (after income tax adjustments). This is based on the average income of the people engaged in commercial or industrial activities in the project area (about two and half times the minimum wages). Those people are assumed to form the majority of railway passengers.

Also, it was supposed that the time value would increase in proportion to the increase of GDP per capita of the State of Guanajuato, which was forecasted according to the data submitted by the State Government.

9-3-2 Savings in maintenance and operation costs

If the maintenance and operation costs for "Without the Project" exceed the costs for "With the Project," the difference can be calculated as minus costs and thus can be viewed as a benefit.

9-4 Evaluation

The contents of evaluating indices were mentioned in 9-1-3. The EIRRs of this project, calculated by the before-mentioned process, are shown in Table 9-4-1.

Table 9-4-1 Comparison of EIRR (%)

	Case 1	Case 2	Case 3
EIRR	10.0	10.5	11.5

As can be seen from the above table, the EIRRs of this project can be regarded to be reasonable, since even the EIRR of Case 1, the lowest among the three cases, equals the internationally acceptable level of 10 percent. The EIRR of each case gradually increases from Case 1 to Case 3, mainly because the capital costs gradually decrease as shown in Table 9-2-1. Concerning the differences of capital costs, initial investment for Case 2 naturally decreases due to the shorter length of railway line. In Case 3, however, the construction section and the type of construction are the same as those in Case 1, thus there is no difference in initial investment between Case 1 and Case 3. The difference in total construction costs between Case 1 and