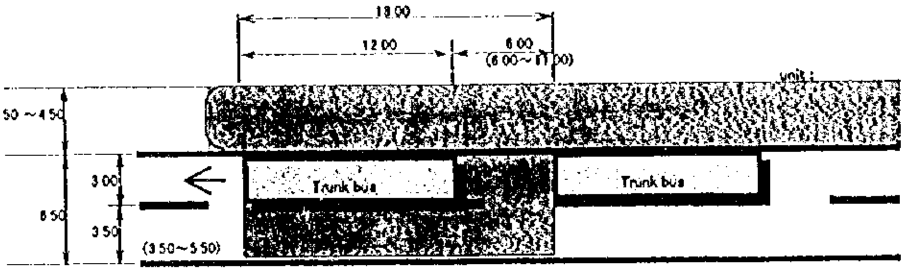
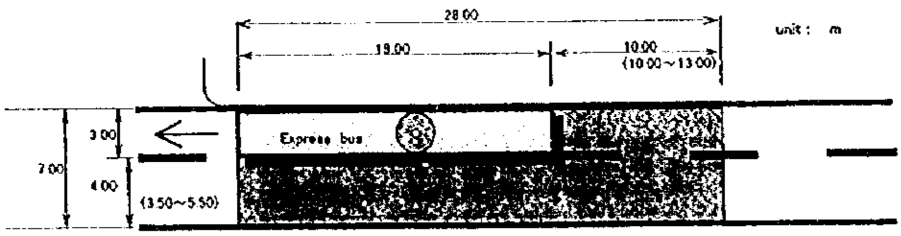
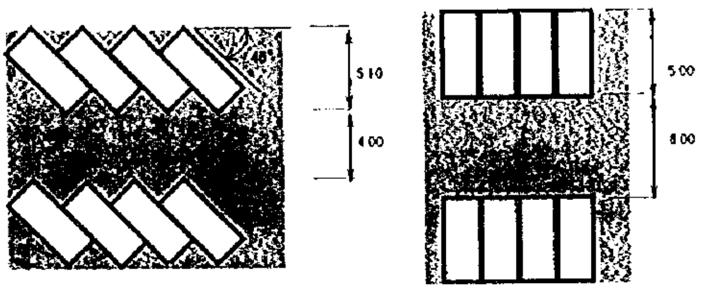
① Trunk buses & Express buses





② Cars



③ Bicycles

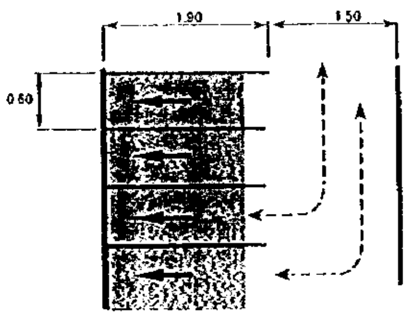


Figure 14.4-2 Unit Area Required for Vehicle Related Facilities

(5) Design of Central Urban Bus Terminal

1) Provisions of Vehicles and Passengers Circulation

The provision for vehicles and passengers circulation are established as follows:

a) Provision for Efficient Bus Circulation

The system for efficient bus circulation is defined as follows:

i) The major access routes for the trunk busway system to the central urban bus terminal are two routes from Avenida Caracas and Aveninda Ciudad de Lima.

ii) These roads provide the most direct access to the bus terminal.

iii) Taking two storied bus terminal buildings into consideration, the bus space for trunk bus and express bus will be separated.

iv) Major gateways of each type of bus are established in Figure 14.4-3, these routes are as described.

- Avenida Caracas gateway route for the trunk bus and express bus:
- From Autopista Norte, Avenida 10a and Autopista Sur via Calle 6 to bus terminal.
- Avenida Ciudad de Lima gateway route for the trunk bus only:
- From Avenida Quito and Autopista Sur via Calle 16 – Carrera 27 to bus terminal.
- The express bus from Avenida Caracas gateway will be directly accessed to and from second floor terminal by viaduct.
- In accordance with construction of expressway, the express bus from Autopista Sur will cross from Calle 6 to Avenida Caracas by grade separation.
- The trunk bus from Autopista Sur to bus terminal will go through Calle16 and Carrera 27 due to physical difficulty of Avenida Cuidad de Quito fly-over.

v) Arrival and departure areas are not separated in the bus terminal area.

vi) Entrance to/from Avenida Caracas and Avenida Ciudad de Lima will be controlled by signalized intersection.

b) Provision for Efficient Pedestrian Circulation

The system of efficient pedestrian circulation is defined as follows:

i) The embarkation area of the express bus will be provided with waiting space for passengers who have passed through a ticketing office. Each departure berth will have a designated waiting area and departure door. The debarkation area of the express bus will lead passengers into the terminal building.

ii) Passengers who are transferring from each type of bus, and walking to any of the other surrounding areas, will be directed to their destination via the large open area of the terminal.

iii) The terminal will be a two storied structure: the second floor is for the use of express bus space, and the ground floor is for the use of trunk, local bus and other public space. Those passengers transferring to the express bus, trunk bus and the local bus will use the pedestrian elevators, decks and bridges.

iv) Passengers who require taxi service or private car from the terminal area will also be directed to the taxi space and car parking space on the ground floor.

c) Provision for Efficient Pedestrian Access to and from the Surrounding Areas

The central urban bus terminal will not only direct bus passengers. It also will facilitate pedestrian traffic for those people who will walk to and from the surrounding areas. From bus terminal, access to the commercial, office and market area, the pedestrian environment shall be improved in order to ensure their safety and enhance the commercial function in this area. Therefore, friendlier atmosphere will be provided in order to improve overall traffic environment by introducing pedestrian mall and green area.

2) Notes on Construction of Bus Terminal

The area defined by Ave. Jimenez, Ave. Lima, Ave. Caracas and Carrera 19 was judged to be the most appropriate for the construction of this terminal. Note however that there are certain problems still to be resolved concerning this location. Planning and design in the future must be with due consideration of the following points:

a) There are building structures to be preserved dotted around the area. If possible, such buildings may be preserved as a monument of the terminal or transferred to other appropriate places.

b) Currently, a plan of redevelopment is on going. It is necessary to justify the plan, which can coexist with and match the concept of the redevelopment plan for the area concerned. The land use and construction plans must meet the requirements of residents and bus users in the surrounding area for improved convenience.

c) This location may be said to be the area most appropriate for construction of the central bus terminal because of the improved convenience through strengthening of the mutual accessibility between the existing bus terminal and metro station, availability of the wide vacant lot, etc.

The plan of the central urban bus terminal and perspective are shown in Figure 14.4-4.

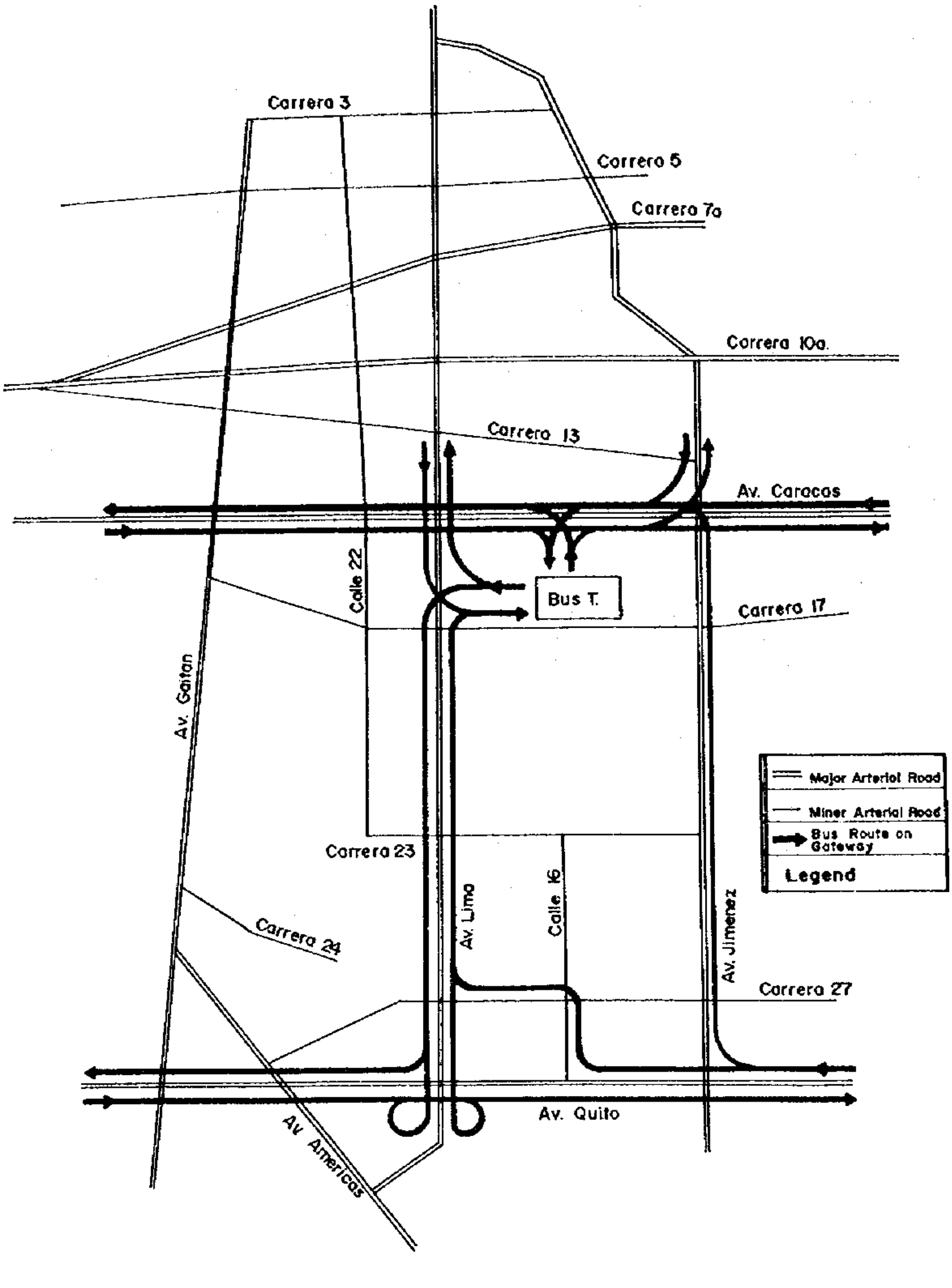


Figure 14.4-3 Gateways of Trunk Busway to Central Urban Busway

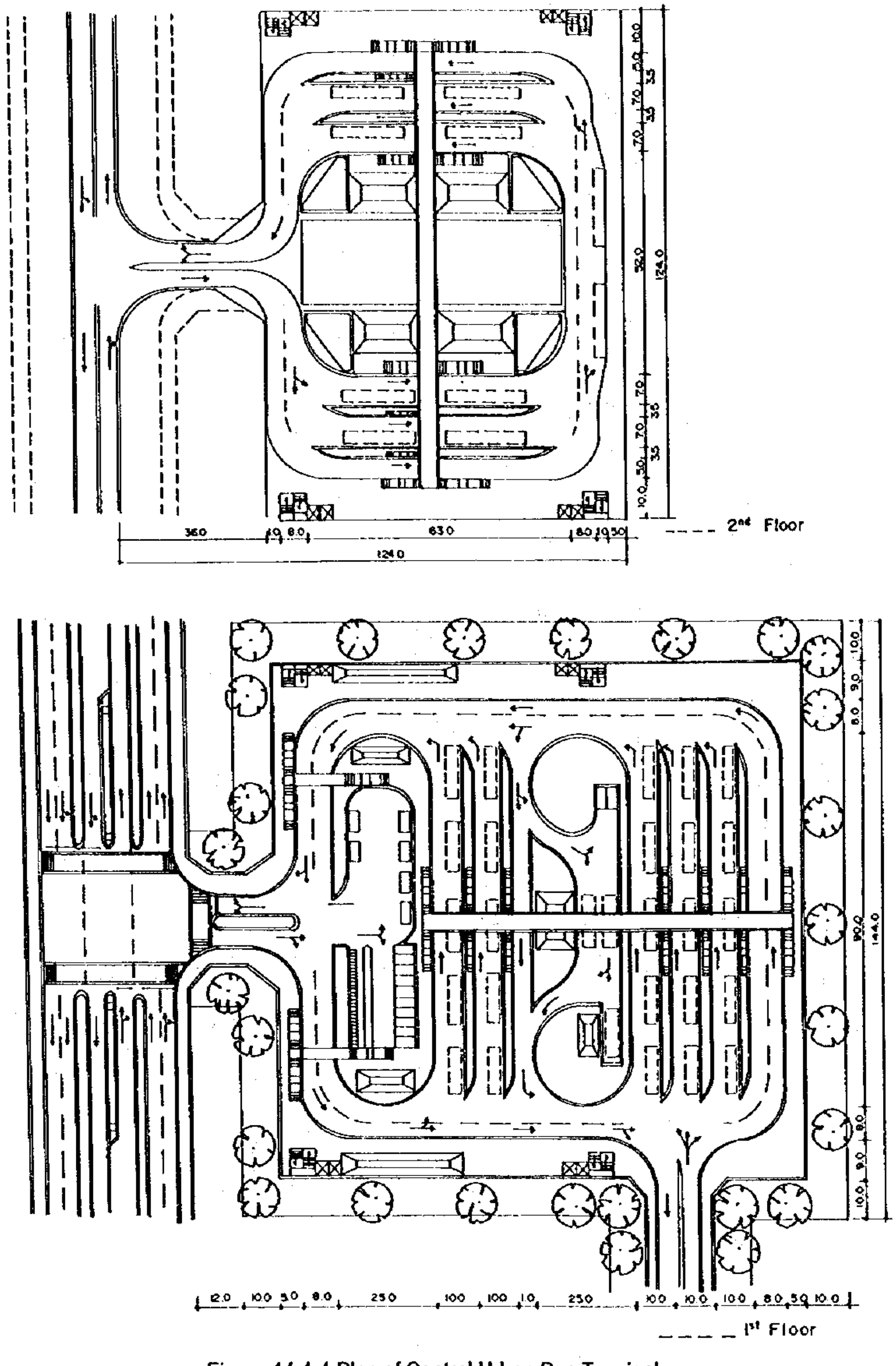


Figure 14.4-4 Plan of Central Urban Bus Terminal

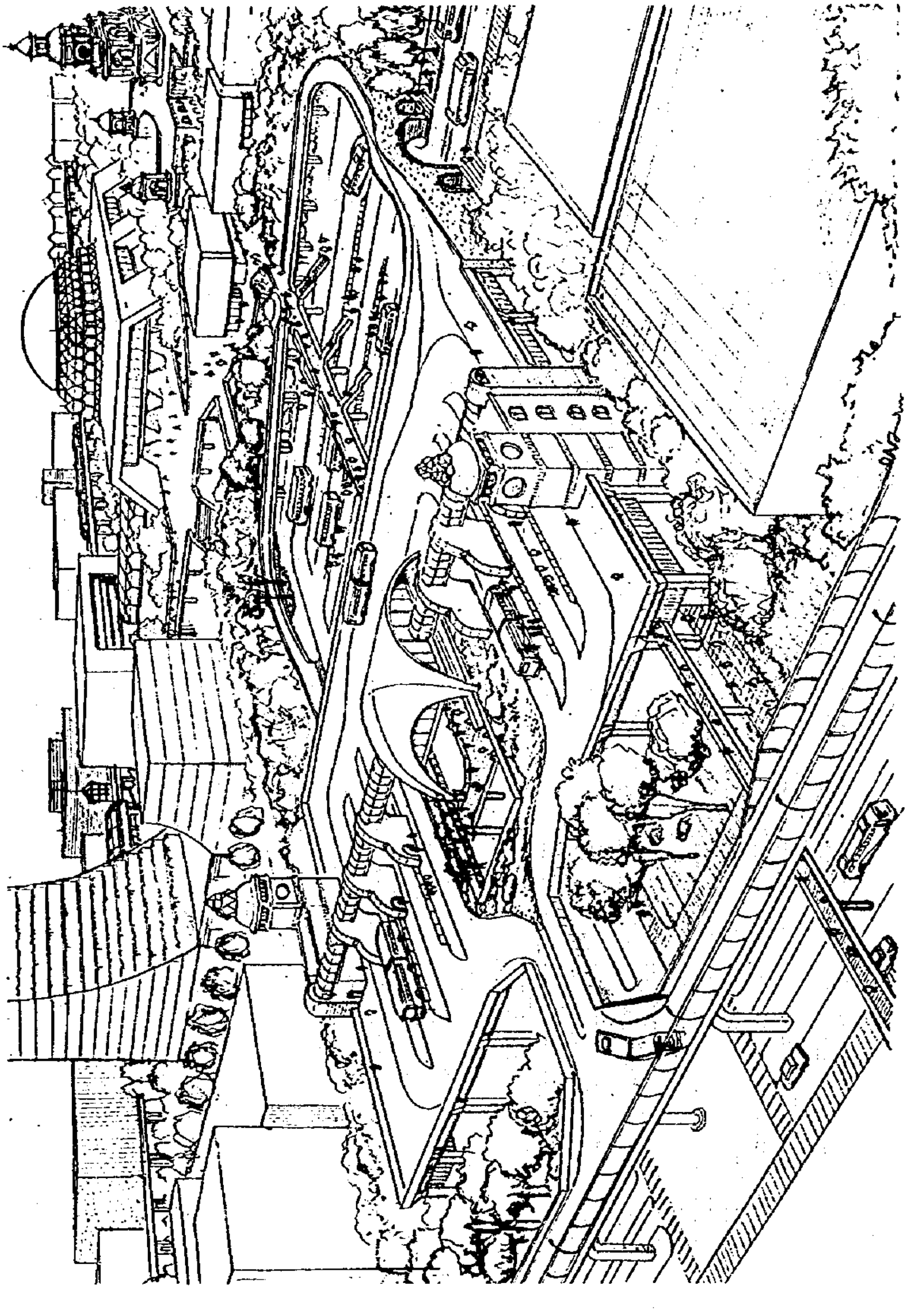


Figure 14.4-5 Perspective View of Imaged Central Urban Bus Terminal

14.4.2. SUBURBAN BUS TERMINAL

The suburban bus terminals will be located near peripheral areas. The suburban terminals will be constructed at terminals and transfer points and used by several bus routes or between local buses.

(1) Major Functions of Bus Terminal

The function of the suburban bus terminal is as follows:

1) End terminal of each trunk bus route.

2) Transfer points among trunk bus routes, express bus and local bus routes

(2) Location of Bus Terminal

1) Selection for Location of Bus Terminal

Appropriate sites were chosen for consideration around start and end points of the trunk bus service shown in Figure 14.4-6. The locations will be selected taking into the following viewpoints:

a) Lands where other use plans are already under way.

b) Lands where there are already structures, and

c) Lands where planning is restricted as a green reserve area.

In addition, the laws were also observed. The permits are given for construction of particularly necessary public facilities considering their public importance (Law enacted in Dec. 29,1994. Article 920. Law enacted in April 16,1997. Article 271):

On the basis of the site survey and the qualitative assessment of strong points and weak points of each alternative, similar to the method of selection central bus terminal, the appropriate locations were selected. The items for assessment are; a) capacity depends on bus demand, b) accessibility of major road, c) connection of Metro stations, d) permission of usage of preservation area, and e) possibility of land acquisition. From this assessment, desirable locations are shown in Figure 14.4-7.

2) Function of Bus Terminal

The major function of the suburban bus terminal plan is almost the same as the central urban bus terminal as discussed in Table 14.4-2. The facility is only for transfer and terminal functions are provided with limited services for transfer of passengers. In 2000, the basic function will be available for bus operator and passengers. In 2005 and after, the bus terminal will fully function with additional service facilities.

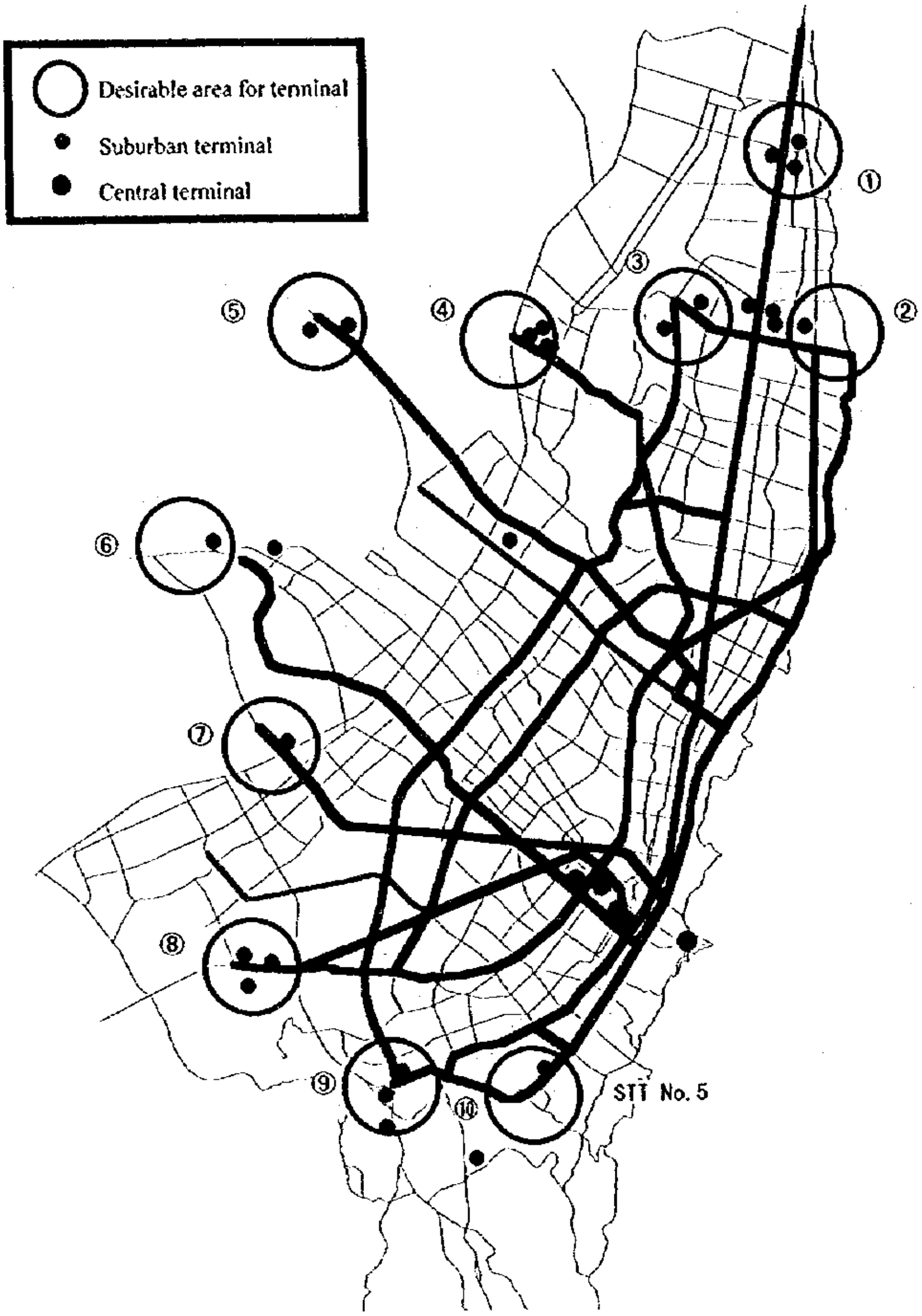


Figure 14.4-6 Alternatives for Location of Suburban Bus Terminals

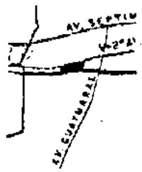
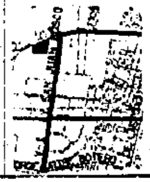
Sector	1	2-3	4	5	6	7	8	9	10-11	12
Localization	**Autopista Norte Por Av. Guaymaral** 	**Av. Séptima Por Av. San José.** 	**Av. San Jose Por Av. Boyaca.** 	**Av. Suba Por Av. Ciudad De Cali.** 	**Av. Medellin Por Rio Bogota** 	**Av. Centenario Por Av. Esperanza** 	**Av. Americas Por Av. Agoberto Mejia** 	**Av. Sur Por Av. Bosa** 	**Av. Boyaca Por Av. Guacamayas** 	**Av. Decima Por Calle 38 Sur** 
Trunk Route	Autopista Norte	Av. Septima Av. Quito	Av. San Jose	Av. Suba	Av. Medellin	Av. Centenario	Av. Americas	Av. Sur	Av. Caracas, Av. Boyaca	Av. Decima
Area	2.7 Ha.	More than 3 Ha.	More than 4 Ha	3.08 Ha	49 Ha	4.5 Ha.	27 Ha	Aprox 1.7 Ha	Aprox. 3 Ha	Aprox 1.2 Ha
Coments	It is possible to make a bigger area if two small lots are united, that locate at the sides of this piece of land denominated "El Descanso" and "Central deTelefonos"		The cost of the soil is very expensive	It isn't over Avenue Suba The access road will be realized on Av. Ciudad de Cali Plan S51/1-12	This peace of land is out of the service perimeter, there is a prohibited of land use Bogota river. Plan E227/1-00	Piece of land out of the service perimeter. Planos F 372/1	Piece of land is restricted by an urban plan of DAPDP Piece of land out of the service perimeter F112/4-01,02	The area is limited	Piece of land without incorporation DAPD	Insufficient area, nowadays in this sector doesn't have more area In the future will be necessary to affect the developed area

Figure 14.4-7 Desirable Locations for Suburban Bus Terminals

(3) Development Needs of Bus Terminal Area

1) Number of Berths and Area Required

The development needs of suburban bus terminal area were determined by the same method as for the central urban bus terminal. The required number of bus berths and land area are shown in Table 14.4-4.

Table 14.4-4 Development Needs of Suburban Bus Terminal

No	Location of bus terminal	Bus (buses/P.H)				Bus berths*					Area(m^2)**				
		Local	Trunk	Express	Total	Local	Trunk	Express	Spare	Total	Local	Trunk	Express	Spare	Total
1	Autopista Norte	235	88	22	345	2	1	1	3	7	229	172	144	430	974
2	Ave. 7a	0	160	0	160	0	3	0	1	4	0	312	0	196	508
3	Calle 170	0	162	0	162	0	3	0	1	4	0	316	0	196	512
4	Ave. Suba	297	79	0	376	2	1	0	2	6	290	154	0	392	836
5	Calle 80	67	99	6	172	1	2	1	3	6	65	193	196	430	884
6	Ave. Centenario	52	44	1	97	1	1	1	3	6	117	86	196	430	829
7	Ave. Americas	107	26	4	137	1	1	1	3	6	104	117	196	430	847
8	Autopista Sur	47	265	80	392	1	4	3	3	11	117	517	523	430	1,586
9	Ave. Boyaca	250	113	13	376	2	2	1	3	8	244	220	196	430	1,090
10	Ave. 10a	237	52	0	289	2	1	0	2	5	231	101	0	392	724

Note: *: Time of bus dispatching and turnover (T.O) by bus type; 1 local bus= 0.5 min/loading, 120 T.O, 1 trunk bus = 1.0 min/loading, 60 T.O, Express=2.0 min/loading, 30 T.O. Ratio of passenger occupancy will be established at 30%.

** Area of bus berth by type; Local/trunk=6.50x18.0m=117.0m^2 Express=7.0x28.0m=196.0m^2

2) Area Required for Public Service Facilities

Regarding the area required for public service facilities, the area required for public service facility will be determined according to the scale of bus berth as shown in Table 14.4-3. The area for each suburban bus terminal is shown as below:

a) Autopista Sur: 7,400 m^2.

b) Others: 5,500 m^2.

3) Area Required for Others

As to the area required for other facilities, these areas were established with the same method as for the central urban bus terminal; the area of pedestrians(footing) is equivalent to 20% of the proposed total area of bus terminal, and the area for vehicle way space is equivalent to 10%.

4) Total Area for Suburban Bus Terminals

From the above, the total area for each suburban bus terminal is summarized in Table 14.4-5.

Table 14.4-5 Total Area for Suburban Bus Terminal

No.	Location of Bus Termi	Area(ha)
1	Autopista Norte	1.0
2	Ave. 7a	0.8
3	Calle 170	0.8
4	Ave. Suba	0.9
5	Calle 80	0.9
6	Ave. Centenario	0.9
7	Ave. Americas	0.9
8	Autopista Sur	1.7
9	Ave. Boyaca	1.0
10	Ave. 10a	0.9

(4) Design of Suburban Bus Terminal

The plan for the typical design of suburban bus terminal is shown in Figure 14.4-8. This plan is the largest scale of suburban bus terminal of Autopista Sur. The plan of other suburban bus terminals can be imaged, by reducing area of bus parking space. The provision of vehicle circulation in bus terminal of Autopista Sur is shown in Figure 14.4-9. Figure 14.4-10 shows the perspective view of imaged suburban bus terminal.

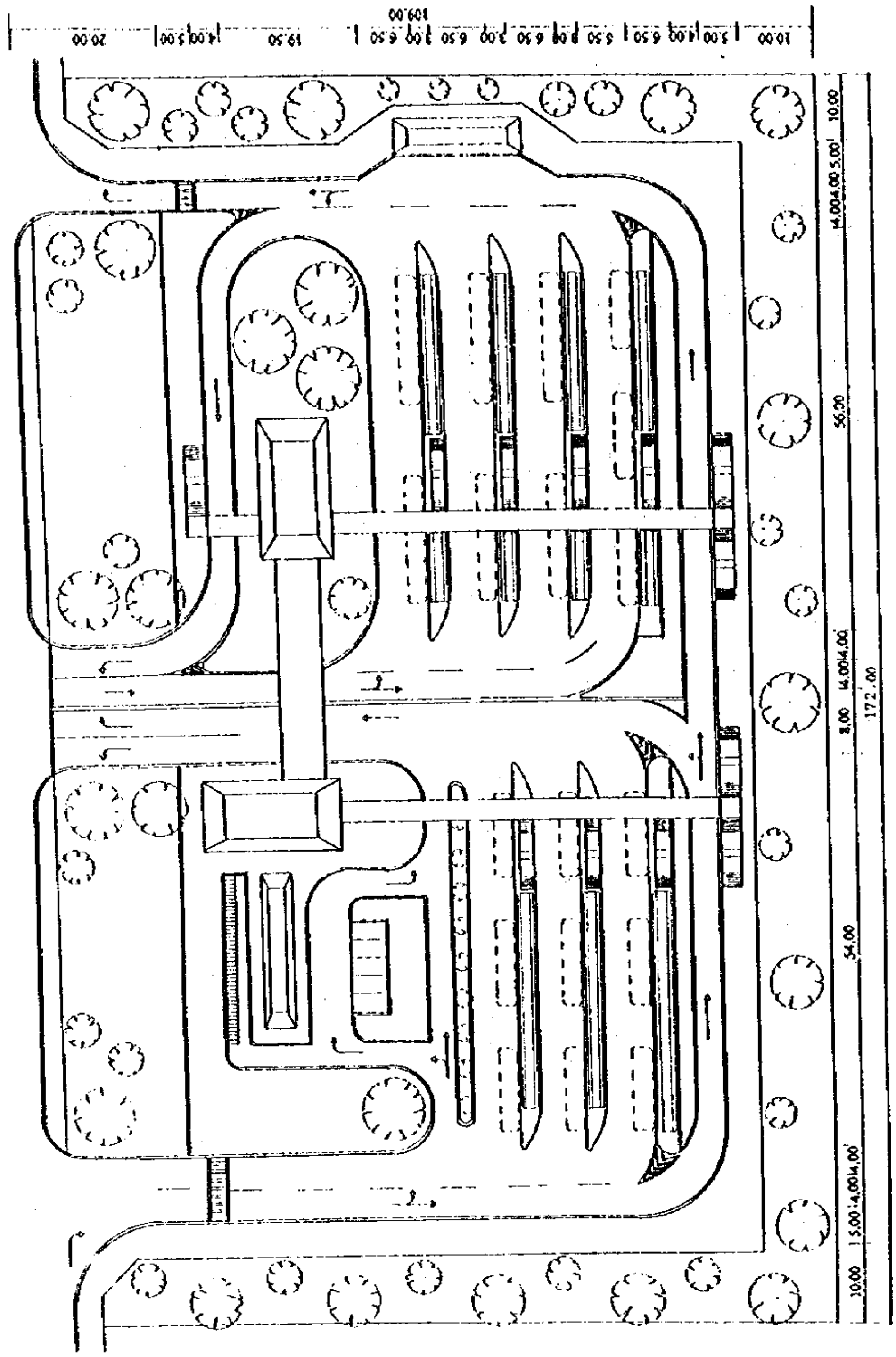


Figure 14.4-8 Plan for Typical Design of Suburban Bus Terminal

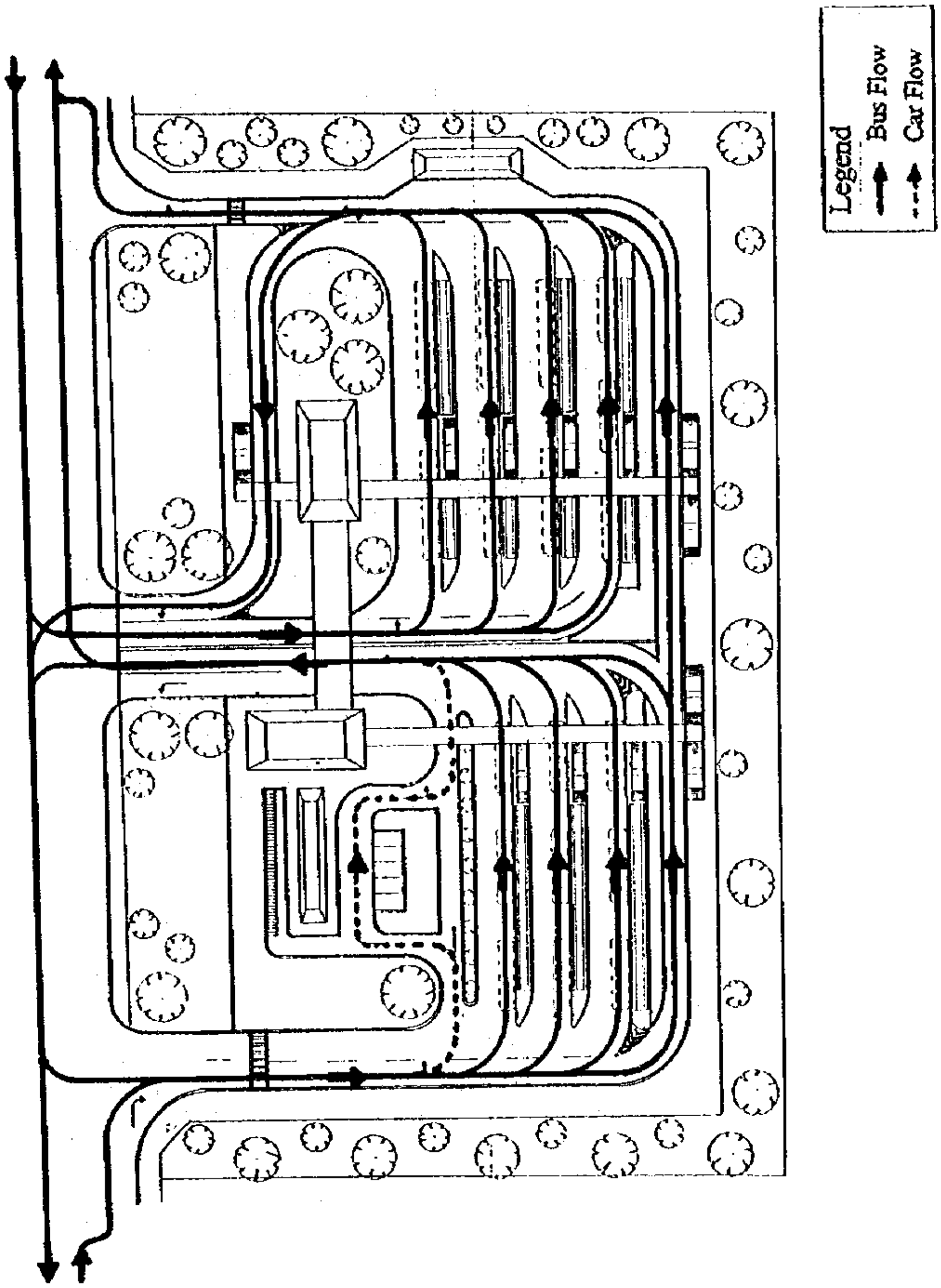


Figure 14.4-9 Vehicle Circulation in Bus Terminal

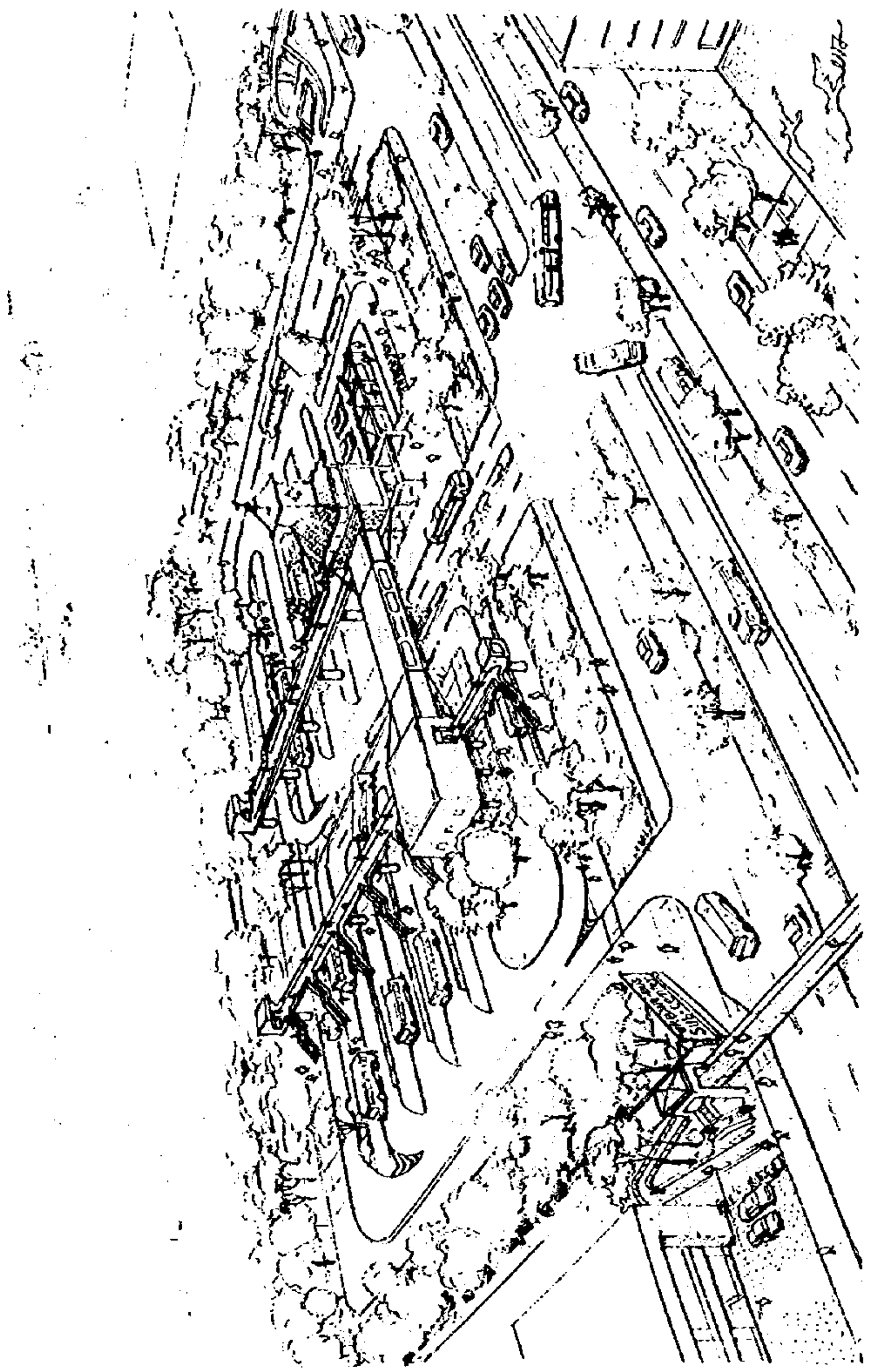


Figure 14.4-10 Perspective View of Imaged Suburban Bus Terminal

14.4.3. Bus U-Turn Facility

The bus U-turn facilities are built at end route of trunk busway for U-turn and bus parking along a curb. These facilities also have a function for terminal and transfer points between trunk and local buses. The U-turn facility is planned on the following conditions:

- Difficulty to acquire sufficient space for bus terminal at the end of routes
- Ease of acquiring sufficient space within existing road space for U-turn

Figure 14.4-11 shows the locations of planned U-turn facilities. These U-turn facilities are classified into two (2) categories by year of construction.

1) Three (3) U-turn facilities to be completed by 2000

2) Two (2) U-turn facilities to be completed by 2005

The three(3) U-turn facilities will be constructed by 2000. One of these facilities is planned between Av. Lima and Av. Jimenez as mentioned in Section 14.4.1, which will be replaced by the central urban bus terminal by 2005. The other two facilities will be located at the intersections between Autopista Norte and Calle 170, and between Av. 13 and Av. 100. The detailed route management is shown in Figure 14.4-12.

In 2005, two (2) U-turn facilities will be added in accordance with bus route network. The detailed route arrangement is also as shown in Figure 14.4-12.

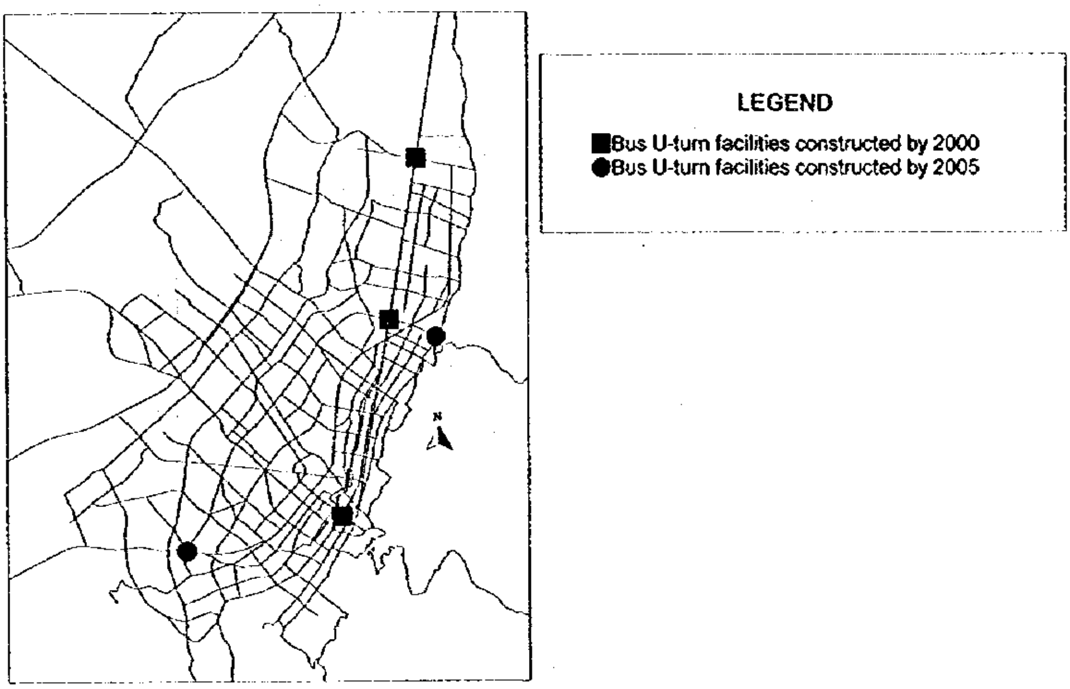
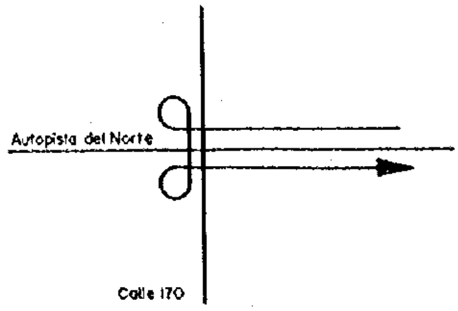


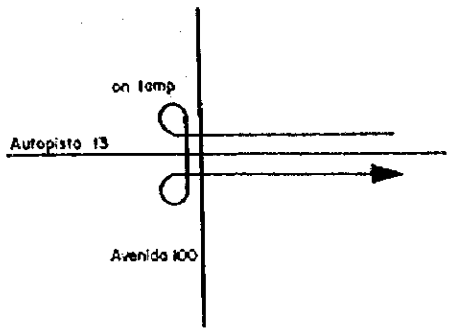
Figure 14.4-11 Locations of Bus U-Turn Facility

1) 2000 year

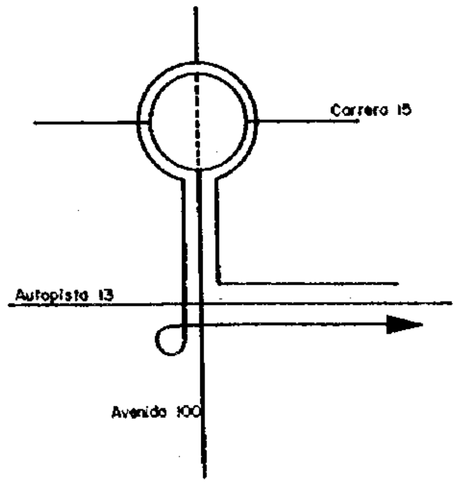
① Autopista del Norte con Calle 170



② Avenida 13 con Avenida 100

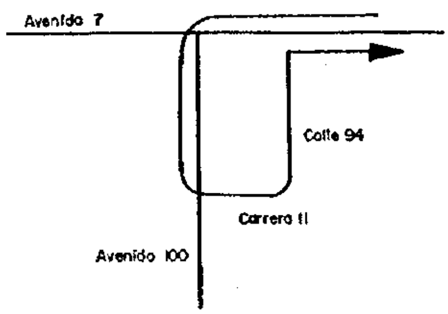


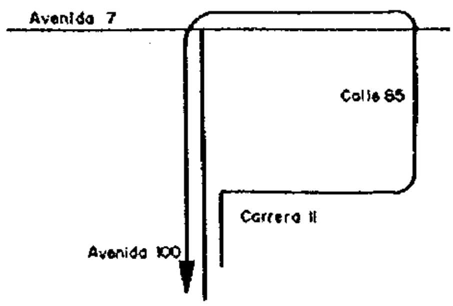
or



2) 2005 year

① Avenida 7 con Avenida 100





② Avenida 68 con Autopista del Sur

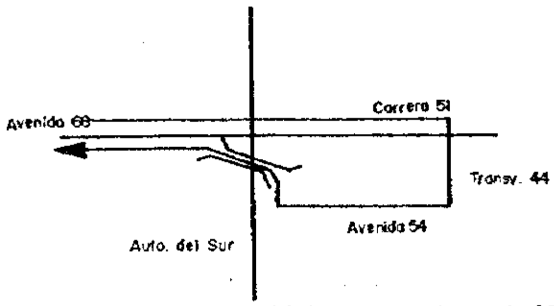


Figure 14.4-12 Route Control of Bus U-Turn Facility

14.5. TRAFFIC SAFETY FACILITIES

With a view to ensuring safety of passengers for the trunk busway and other traffic systems, it is necessary to install traffic safety facilities. The traffic safety facility for passengers shall be installed in order to ensure their safety of crossing at bus stop. On the other hand, the trunk busway usage will be signaled to drivers of other traffic by overhead lane direction signs (gantry and pedestrian bridge), variations in lane color, and lane-use designators or location of bus stop on carriage-way (road marking, traffic reflector and chatter bar). As a general rule, overhead lane direction signals will be provided at the major intersections and interchanges. Besides, the trunk busway usage will be notified by variations in lane color and road marking. In the area outside the trunk busway section, guide signs will be installed about 100 meters upstream from trunk busway section in order to warn drivers of other traffic. The traffic safety facilities are shown as below:

1) Traffic signal light for passengers crossing.
2) Guides signboard for passengers crossing.
3) Overhead lane direction sign.
4) Road marking.
5) Traffic reflector
6) Chatter-bar.
7) Guard fence.

1) Traffic Safety Facilities for Passengers

The traffic safety facility is composed of traffic signal lights and guide signboards for passengers crossing at bus stop on median. These safety facilities are provided for bus stops or trunk bus at signalized intersections. The traffic signal light for passengers crossing is installed at the entrance and exit of bus platform. The guide signboard is functioned to warn passengers by lamp indicator, such as "walk" and "Stop". This safety facility is shown in Figure 14.5-1.

2) Traffic Safety Facility for Other Traffic

The traffic safety facility for other traffic shall be installed in order to protect from collision of bus stop facility and buses. These safety facilities include overhead lane direction signs, road marking, traffic reflector, chatter-bar and guard fence. Figure 14.5-1 shows the safety facilities for other traffic.

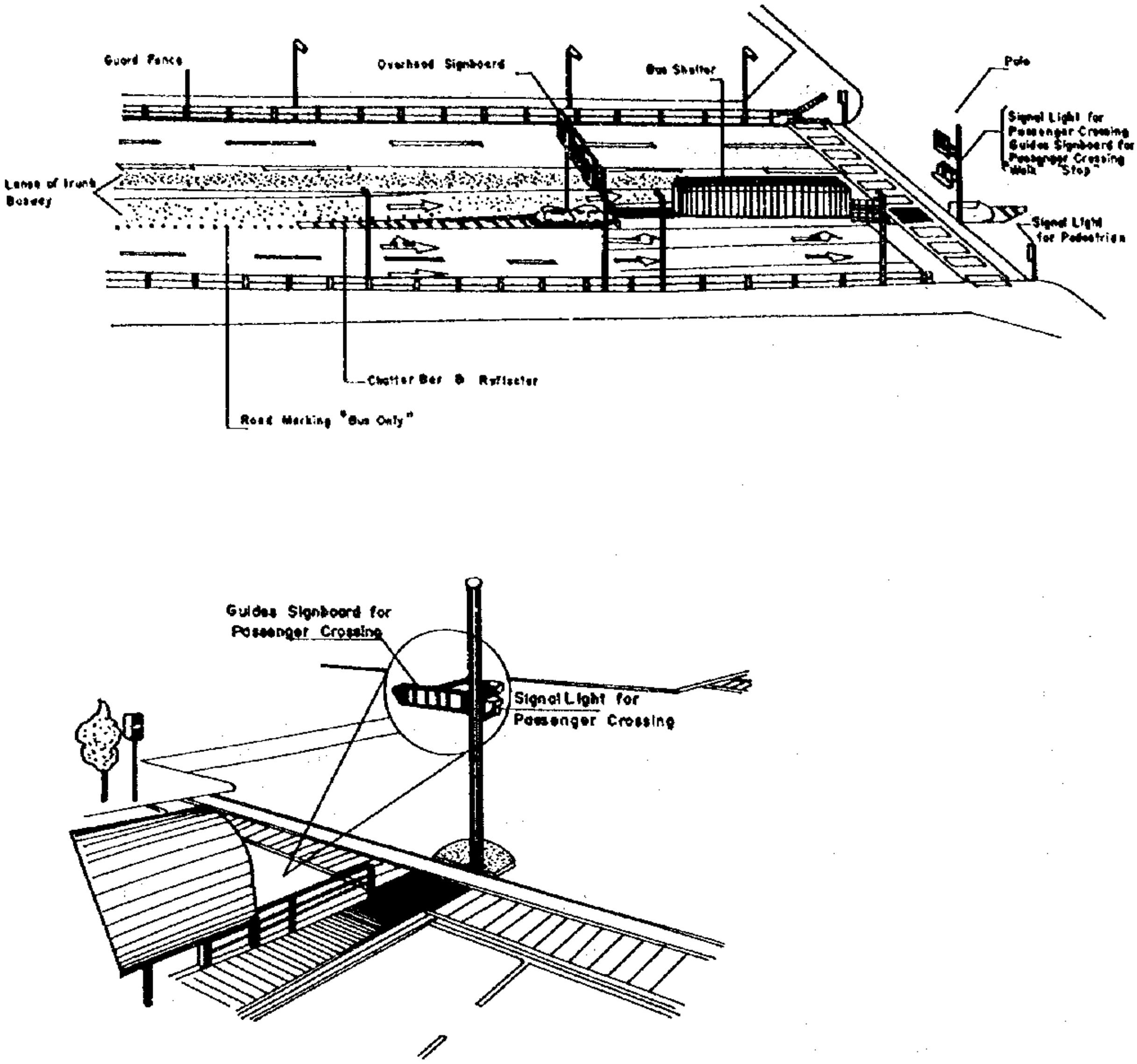


Figure 14.5-1 Traffic Safety Facility

14.6. PRELIMINARY DESIGN CONSIDERED ENVIRONMENT ASPECT

In the express and trunk busways, the full segregated structure from private mode is proposed in the Study. Especially, the structure type of express busway on Av. Caracas proposes a type of viaduct structure with utilizing a road space on Av. Caracas. Environmental aspect such as urban landscape and noise pollution was considered in the preliminary design stage of the viaduct structure. The mitigation measures for the environment was studied in the related Chapters. In this Section, the measurement in the preliminary design stage is summarized.

(1) Viaduct Structure and Landscape

The viaduct busway with a width of 10m is planned on Av. Caracas in which road width is approximately 40m. The clearance between a side of viaduct structure and road side building is approximately 15m. Although it is not desirable to construct the viaduct in the place to be 15m away from buildings, a distance of 10m or more will be acceptable.

As for a visual impact when pedestrians look up the viaduct from sidewalk on Av. Caracas, in general, people feels tolerable when their eyesight area within 60 degree of view angle are covered by the buildings. Since the eyesight is within 30 degree on Av. Caracas, it can be said that there is no major visual damage from the viaduct structure.

Noise barrier made of transparent board with 5m high is installed on the viaduct to mitigate visual impacts from road side buildings, i.e. it is possible to indirectly visualize running vehicles on viaduct.

(2) Pier Type of Substructure and Aesthetics

In order to maintain a particular visual space along roadside, the degree of height of the bridge piers is higher, in contrast to that of normal design. Although in general, a clearance on roads is enough for 8m, the clearance between carriageway on the viaduct structure and on Av. Caracas is approximately 11m, taking into account the visual space.

The design of bridge pier harmonizes with landscape near surrounding area. The surface of pier is covered with bricks.

(3) Road Structure and Mitigation Measures

Daytime noise level in 2015 along Av. Caracas is estimated at 70 – 75dBA on receptor position (the boundary between public and private property with 1.0m high from ground level). These figures are slightly higher than the standard value in the commercial land use area. In order to decrease the noise level, noise barriers are provided on the viaduct structure, while not installed on grand level on Av. Caracas due to no space for installation of barrier. Even though noise barrier are provided on the viaduct, the level slightly decreases by 2dBA on pedestrian walk, while places on two or three floors in building are sufficiently effective. From this point of view, noise barriers with 5m high are proposed on the viaduct structure on Av. Caracas.

(4) Trunk Bus System and Environment

The trunk bus system project has effectiveness for decrease of bus traffic volume and at same time, traffic congestion in Bogota is improved. As a result of improvement of traffic congestion, noise and air pollution are improved. It will be said that the trunk bus system project is a project for environment improvement.

In future, the express busway with viaduct structure on Av. Caracas is strongly proposed for designing the structure to accommodate future rail transit like a LRT. This project will produce good environment conditions.

(5) Express Busway and Preservation

DAPD surveys and summarizes major historical, cultural, monumental buildings or facilities to be preserved. According to reports by DAPD, in Bogota there are many preserved buildings and facilities nominated by DAPD. Those buildings are summarized in the Drawing Report in the Study report.

Since the elevated express busway is constructed on the same road site as that on Av. Caracas, it is not necessary to purchase for additional land acquisition. The removing or demolition of the preserved buildings and facilities nominated by DAPD does not occur for this design concept.

CHAPTER 15
Preliminary Design for Inner Ring Expressway

15. PRELIMINARY DESIGN FOR INNER RING EXPRESSWAY

In previous section 11, three (3) Alternative Route Plans such as Route-1, Route-2 and Route-3 were identified, and the Alternative Route-3 was selected for the route of Inner Ring Expressway (IRE) in section 13. The preliminary design is carried out based on the Alternative Route-3, located on the following existing roads.

1) On the Avenida 7a (Section between Calle127 and Calle 100)
2) On the Calle 100 (Section between Avenida 7a and Carrera 15)
3) On the Avenida Quito (Section between Carrera 15 and Calle 6)
4) On the Calle 6 (Section between Avenida Quito and Avenida Caracas)

15.1. DESIGN CRITERIA

15.1.1. DESIGN STANDARDS

In Colombia, they have 2 design manuals: road design standards namely "Manual de Diseno Geometrico para Carreteras" and "Manual para el Diseno de Pavimentos Flexibles de Santa Fe de Bogota". However, when a new road is designed, the American road design standards namely "A Policy on Geometric Design of Highways and Streets (by AASHTO)" is generally adopted. In determining the geometric design elements to be adopted in this study it was decided to refer three design manuals: the Colombia design manual, the American standards, and the Japanese design standards. The major geometric design elements are compared below.

(1) Minimum Radius of Horizontal Curve

The comparison of minimum radius of horizontal curve among the above standards is shown in Table 15.1-1.

Table 15.1-1 Comparison Table of Minimum Horizontal Curve

Design Speed	Colombian	American	Japanese	Remarks
40 km/h	50 m	60 m	60 m	
60 km/h	120 m	150 m	150 m	
80 km/h	235 m	280 m	280 m	
100 km/h	415 m	490 m	460 m	

(2) Maximum Longitudinal Grade

The comparison of maximum longitudinal grade on flat terrain among the three standards is shown in Table 15.1-2. The minimum longitudinal grade is adopted at 0.3 % to 0.5 %, considering the drainage conditions of the carriageway.

Table 15.1-2 Comparison of Maximum Grade

Design Speed	Colombian	American	Japanese	Remarks
40 km/h	7-11 %	7 -9%	7 -9%	
60 km/h	6- 8 %	6-8%	6 -8%	
80 km/h	4- 6 %	4 -5%	4 -5%	
100 km/h	3- 5 %	3 -4%	3 -4%	

(3) Passing Sight Distance

The passing sight distance among the three standards is summarized in Table 15.1-3.

Table 15.1-3 Comparison of Sight Distance

Design Speed	Colombian	American	Japanese	Remarks
40 km/h	200 m	285 m	150 m	
60 km/h	300 m	407 m	250 m	
80 km/h	400 m	514 m	350 m	
100 km/h	500 m	670 m	500 m	

(4) Design Speed

There are no standards in Colombia regarding design speed for urban expressways. The design speed (At-grade type) on roads is generally used as 80 km/h to 110 km/h. The design speed of urban arterial streets in American and Japanese standards is usually not less than 80 km/h and 60 km/h to 80 km/h, respectively.

Taking into account the existing road alignment and road side facility conditions, functions of the IRE, the above mentioned criteria, and the building conditions along existing roads (possibility of demolition of buildings), the 60 km/h to 80 km/h design speed is adopted for the IRE.

(5) Vertical Clearance

According to the Colombian road design manual and Japanese road design standards, the vertical clearance for vehicles is identified at 4.5m, and many existing bridges in the city of Bogota are constructed with a clearance of 4.5m. The vertical clearance adopted in the Study is 4.5m for the IRE.

15.1.2. GEOMETRIC DESIGN ELEMENTS ADOPTED IN THE STUDY

Based on the results of field reconnaissance survey on the existing roads, facilities and building conditions along the roads, as well as environmental conditions along the roads, the preliminary design of the IRE is conducted. As the result of preliminary design, the geometric design elements adopted for the IRE are shown in Table 15.1-4. The minimum geometric standards on the 60 km/h design speed are shown in "Remarks" column in this table.

Table 15.1-4 Element of Geometric Design Adopted for IRE

Items	Unit	Elements	Remarks
Mini. Curvature	m	150	120 to 150
Max. Grade(Road)	%	2.8	4 to 6
Max Grade(Ramp)	%	6.0	6 to 8
Mini. Grade(Road)	%	0.5	0.3 to 0.5
Mini. Grade(Ramp)	%	0.5	0.3 to 0.5
Superelevation	%	2.0	1.5 to 2.0
Stopping Sight Distance	m	85	
Vertical Curves (sug.)	m	1,500	
Vertical Curves (crest)	m	2,000	
Lateral Clearance(Right)	m	1.0	
Lateral Clearance(Left)	m	0.5	
Vertical Clearance	m	4.5	4.5

15.2. TYPE OF ROAD STRUCTURE ADOPTED.

In general, three (3) different road structure types for the urban expressway: At-grade type, Viaduct type, and Tunnel type can be considered. The at-grade type is a road constructed at the same level as that on existing roads. The viaduct type is a road constructed for use over the space of the existing roads. The tunnel type is a road constructed for use under the space of existing roads. As mentioned previously, the Inner Ring Expressway (IRE) uses the space of the existing road areas, because there is no room to construct the IRE along the existing roads, as well as to utilize the existing road facilities. In this section, three (3) road types are studied to select the optimum road structure type for the IRE taking into account of the existing road facilities or structures conditions, as well as considering the preservation of the natural and social environmental aspects.

15.2.1. EXISTING ROAD FACILITIES ON AVENIDA QUITO.

The route of the Alternative Route-3 is located on the existing roads of Avenida 7a, Calle 100, Avenida Quito, and Calle 6. The major intersections located on Avenida Quito are constructed with grade-separated intersections as shown in Table 15.2-1, and Figure 15.2-1, respectively. The minor intersections located on Avenida Quito are at-grade type with or without signal.

The above mentioned over-bridges are constructed using pre-stressed concrete (PC) type with four or five spans as shown in Figure 15.2-2 and Figure 15.2-3. The distances between bridge piers are about 15 meters to 20 meters, and these piers are constructed on pile foundations with about 40 meters pile lengths.

In addition to the over-bridges, there are many pedestrian bridges constructed using PC structure with three and four spans. These pedestrian bridges are located at intervals of 500 to 600 meters along Avenida Quito.

Table 15.2-1 Intersection Type on Avenida Quito.

Location of Intersection	Distance of Intersection (m)	Type of Intersection	Remarks
Call100 and Av.7a		Over-bridge by Calle100	
Calle 100 and Ve. Quito	1,250	Tunnel by Av. Quito	
Av. Quito and Auto. Norte	1,350	Over-bridge by Auto. Norte	
Av. Quito and Av. 80	1,100	Over-bridge by Av. 80	
Av. Quito and Calle 72	950	Over-bridge by Calle 72	
Av. Quito and Calle 68	550	Over-bridge by Call68	
Av. Quito and Calle 53	1,050	Over-bridge by Call53	
Av. Quito and Calle45	900	Over-bridge by Calle 45	
Av. Quito and Calle 28	250	Over-bridge by Call28	
Av. Quito and El. Dorado	600	Over-bridge by Av. Quito	
Av. Quito and Americas	350	Over-bridge by Americas	
Av. Quito and Av.Lima	950	Over-bridge by Av. Lima	
Av. Quito and Calle 13	600	Over-bridge by Va. Quito	

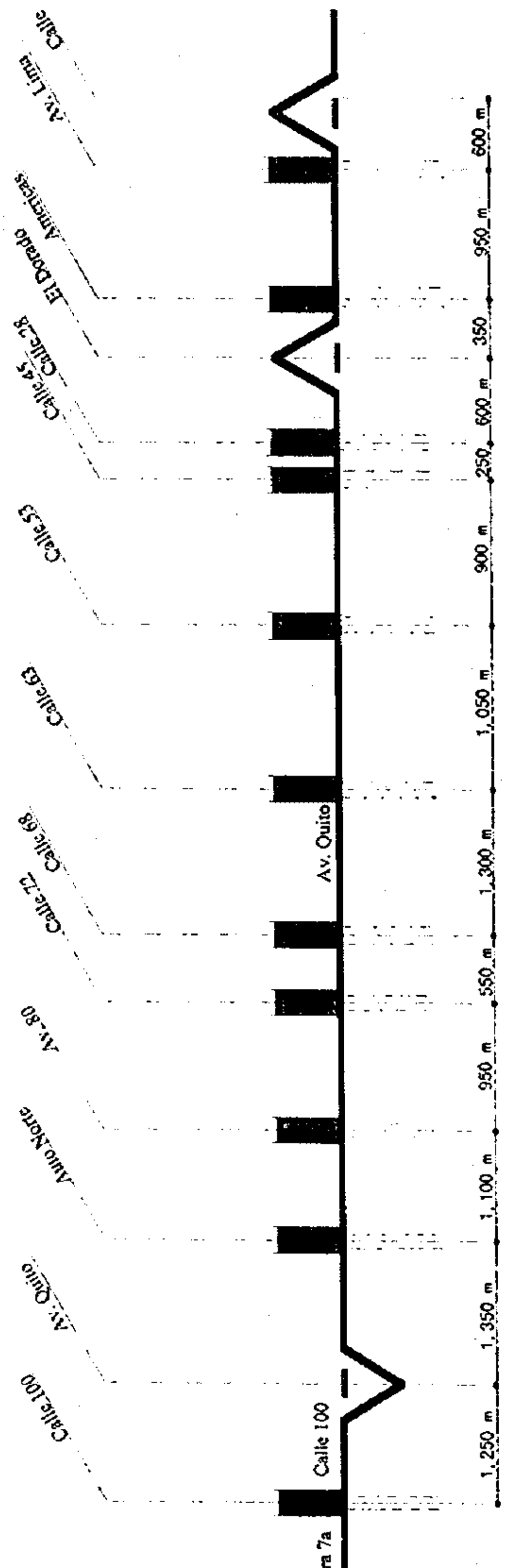


Figure 15.2-1 Location of Over-bridge on Avenida Quito

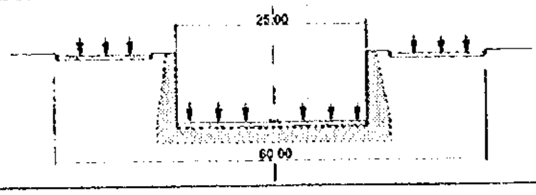
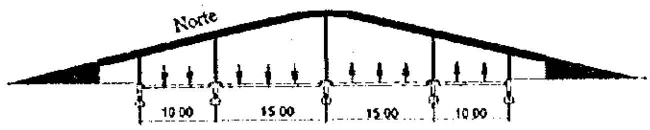
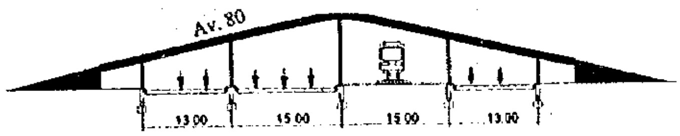
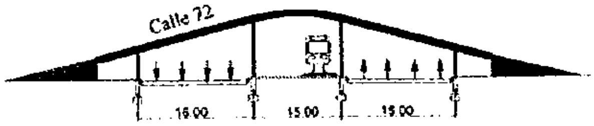
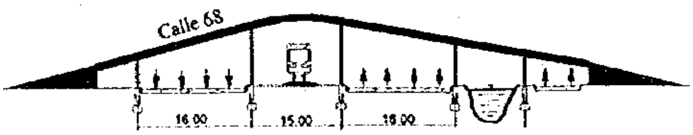
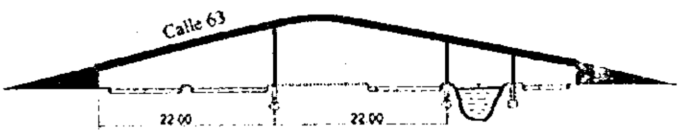
Name of Main Road	Name of Cross Road	Over-Pass Road	General View of Over Bridge.
Av. 7a (calle 100-116)	Calle 100	Calle 100	
Calle 100 (7a-quito)	Av. Quito	Calle 100 (under pass)	
Av. Quito	Auto Norte	Auto Norte	
Av. Quito	Av. 80	Av. 80	
Av. Quito	Calle 72	Calle 72	
Av. Quito	Calle 68	Calle 68	
Av. Quito	Calle 63	Calle 63	

Figure 15.2-2 General Profile of Over-bridge on Avenida Quito(1)

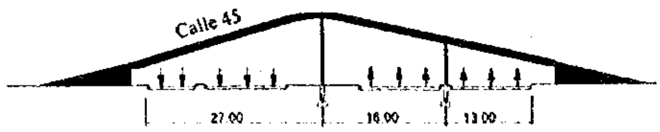
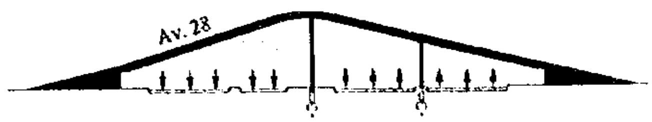
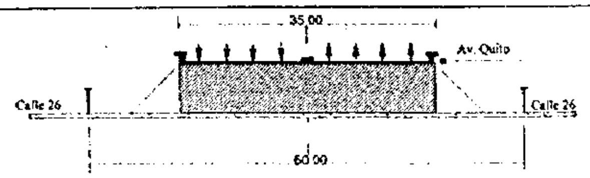
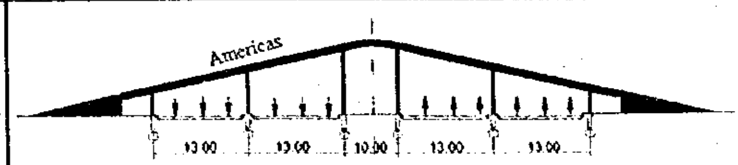
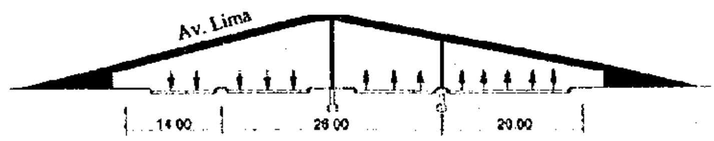
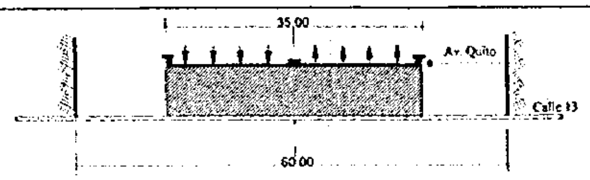
Name of Main Road	Name of Cross Road	Over-Pass Road	General View of Over Bridge
Av. Quito	Calle 53	Calle 53	
Av. Quito	Calle 45	Calle 45	
Av. Quito	Av. 28	Av. 28	
Av. Quito	Calle 26 (Dorado)	Av. Quito	
Av. Quito	Auto Americas	Auto Americas	
Av. Quito	Av. Lima	Av. Lima	
Av. Quito	Calle 13	Av. Quito	

Figure 15.2-3 General Profile of Over-bridges on Avenida Quito (2).

15.2.2. SELECTION OF ROAD STRUCTURE TYPE FOR INNER RING EXPRESSWAY (IRE)

As mentioned previously, the evaluated structure type is employed. The major reasons of the selection are as followings.

(1) Regarding to At-grade Road Type

In case of the at-grade road type, the total road width needed for 4-lane dual carriageway without sidewalks is about 20 meters. In spite of the fact that Avenida Quito has the 60 meter's right of way, there is no room to construct the IRE on the existing roads. This is because many office or commercial buildings and housing are located along the Avenida Quito, and it is very difficult to demolish these buildings. Considering the condition of these buildings along the Avenida Quito, the at-grade road type should be eliminated as an option for the IRE.

(2) Regarding to Tunnel Road Type

In case of the tunnel road type, the IRE would be constructed using the space under the existing Avenida Quito. However, there are many over-bridges with multiple span which are to be constructed (span length is about 15 meters to 20 meters each) with pile foundation using about 40 meters pile lengths on the Avenida Quito as shown in Figure 15.2-2 and Figure 15.2-3. If the tunnel type road will be constructed, the road should be constructed in a depth of 50m or more below the existing ground level. Considering the construction method of tunnel, location of on-off ramp, and the economic aspects, it is very costly and difficult to construct the tunnel type under the Avenida Quito.

(3) Regarding to Viaduct Road Type

If the viaduct road type is adopted, the IRE will be constructed over the space of Avenida Quito. The IRE should also pass over the existing over-bridges which are located at the major intersection on the Avenida Quito as shown in Figure 15.2-2 and Figure 15.2-3. Since the planning height of the IRE (Pavement height) is required to keep a clearance of 14 meters above Avenida Quito to cross over those bridges, the natural and social environmental aspects should be carefully considered.

15.3. ALIMENT DESIGN

The alignment design consists of two categories: horizontal and vertical. The horizontal alignment design is carried out based on each road segment, because cross section element is different by each road segment. The horizontal alignment should be met to the following conditions.

1) Location and conditions of plantations on median and sidewalks.
2) Building conditions along the road
3) Land use conditions along the road
4) Width of Carriageway
5) Width of median and sidewalks
6) Viaduct structure type
7) Location of railway
8) Location of water supply pipe
9) Electric power line

The vertical alignment design is carried out by examining the vertical clearance of existing over-bridge heights, conditions of the over-bridge structures, and the future development plan for construction of over-bridges or pedestrian bridges.

15.3.1. Alignment on Avenida 7a (Section between Calle 116 and Calle 100)

(1) Horizontal Alignment

The cross section elements of Avenida 7a (road section between Calle 116 and Calle 100) is influenced by the following facilities or cross section elements as shown in Figure 15.3-1.

1) 5.0 meters sidewalks are located on both sides of road.
2) 10 to 20 meters tall trees are planted on median and outside medians.
3) There is no plantating on the sidewalks.
4) The military school is located on both sides of the road.
5) There are many housing buildings along both sides of the road
6) There is a 24 inches water pipeline.

Considering the above mentioned road facilities and cross section elements, two alternative alignment plans: Alternative-A and B are identified as shown in Figure 15.3-1. As a result of comparative examination, Alternative -A is selected for the horizontal alignment of the IRE. The three-dimension section of Alternative-A is shown in Figure 15.3-2 and Figure 15.3-3 illustrating the layout. The major reasons selected are as follows;

1) The existing three (3) lines of road plantings on the median should be removed under Alternative-A. However, new planting can be installed on both sides of the sidewalks. Since these planted trees which are located along the existing road can cover the structures of IRE, the influence of landscape in the urban area is decrease. From the view points of the landscape conditions, Alternatives A and B are almost the same in the influence of landscape.
2) There will be about 15 to 18m space between the IRE and the buildings under Alternative-A. However, Alternative-B can only provide less than 10 meters. From viewpoints of the inhabitants along the Avenida 7a, Alternative-A is better than Alternative –B. Additionally, from the standpoint of the protection from noise and air pollution, Alternative-A has less effect than Alternative-B.
3) From viewpoints of the construction cost and construction method, the cost under Alternative-A is lower than Alternative-B.

(2) Vertical Alignment

At present, there is no over-bridge on Avenida 7a in the segment between Calle 116 and Calle 100. However, a pedestrian bridge for pedestrians who cross the trunk busway will be needed on Avenida 7a, for traffic safety of pedestrians. Considering the above-mentioned conditions, the proposed road height of IRE will need at a clearance of 11.0m or more above the existing pavement of Avenida 7a. Taking into account the following structure's clearance or beam depth, the 11.0m clearance is required.

a) Vertical clearance of vehicle on Av, 7a: 4.5 m
b) Clearance for maintenance of Av.7a: 0.5 m
c) Beam depth of pedestrian bridge: 1.0 m
d) Vertical clearance for pedestrian: 2.5 m

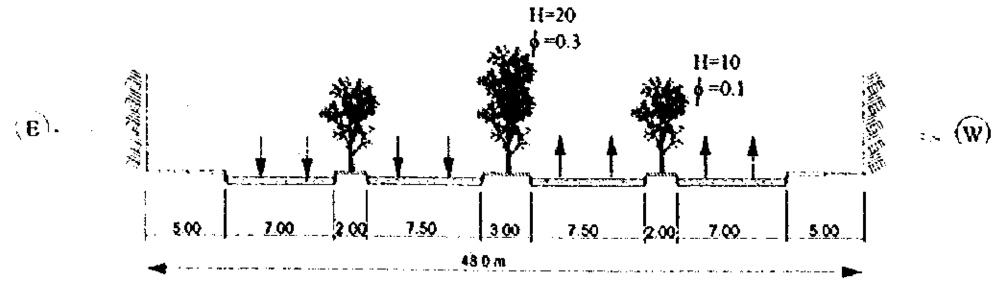
e) Clearance for pedestrian bridge: 0.5 m

f) Beam depth of Inner Ring Expressway: 2.0 m

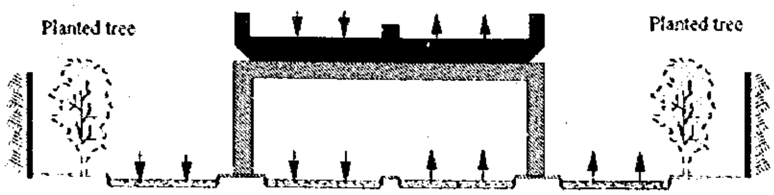
g) Total clearance required: 11.0 m

1. AVENIDA 7a. (Calle 116 - Calle 100)

(1). Existing Cross-Section



(2). Alternative - A



(3). Alternative - B

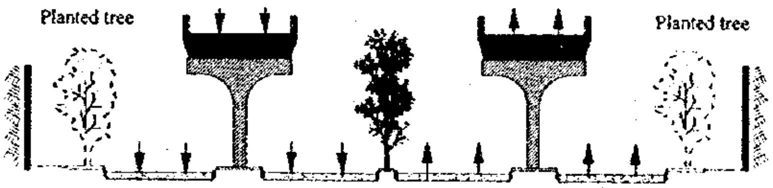


Figure 15.3-1 Alternative Alignment Plans on Avenida 7a

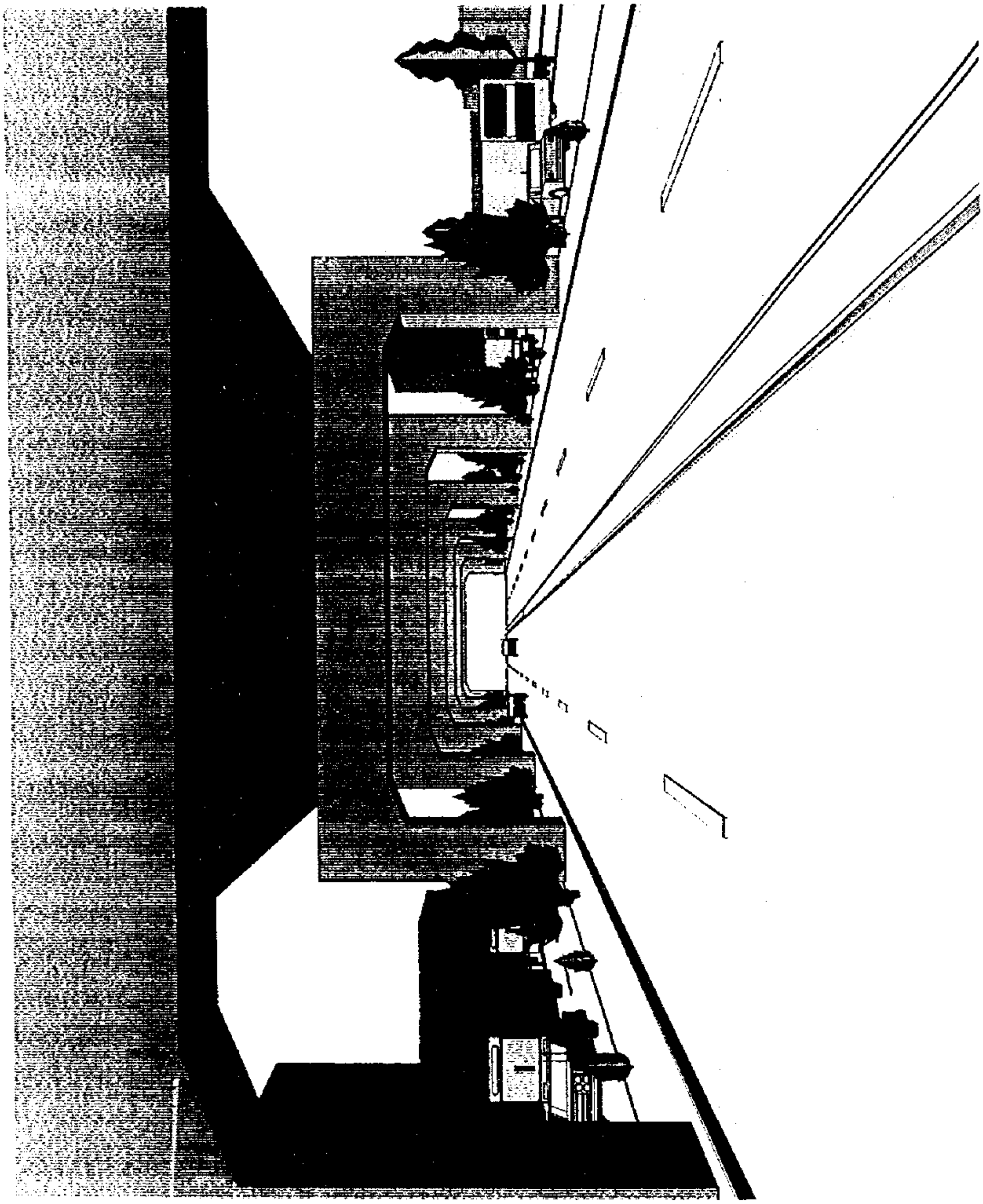


Figure 15.3-2 Three Dimension Plan of Alternative-A(1)

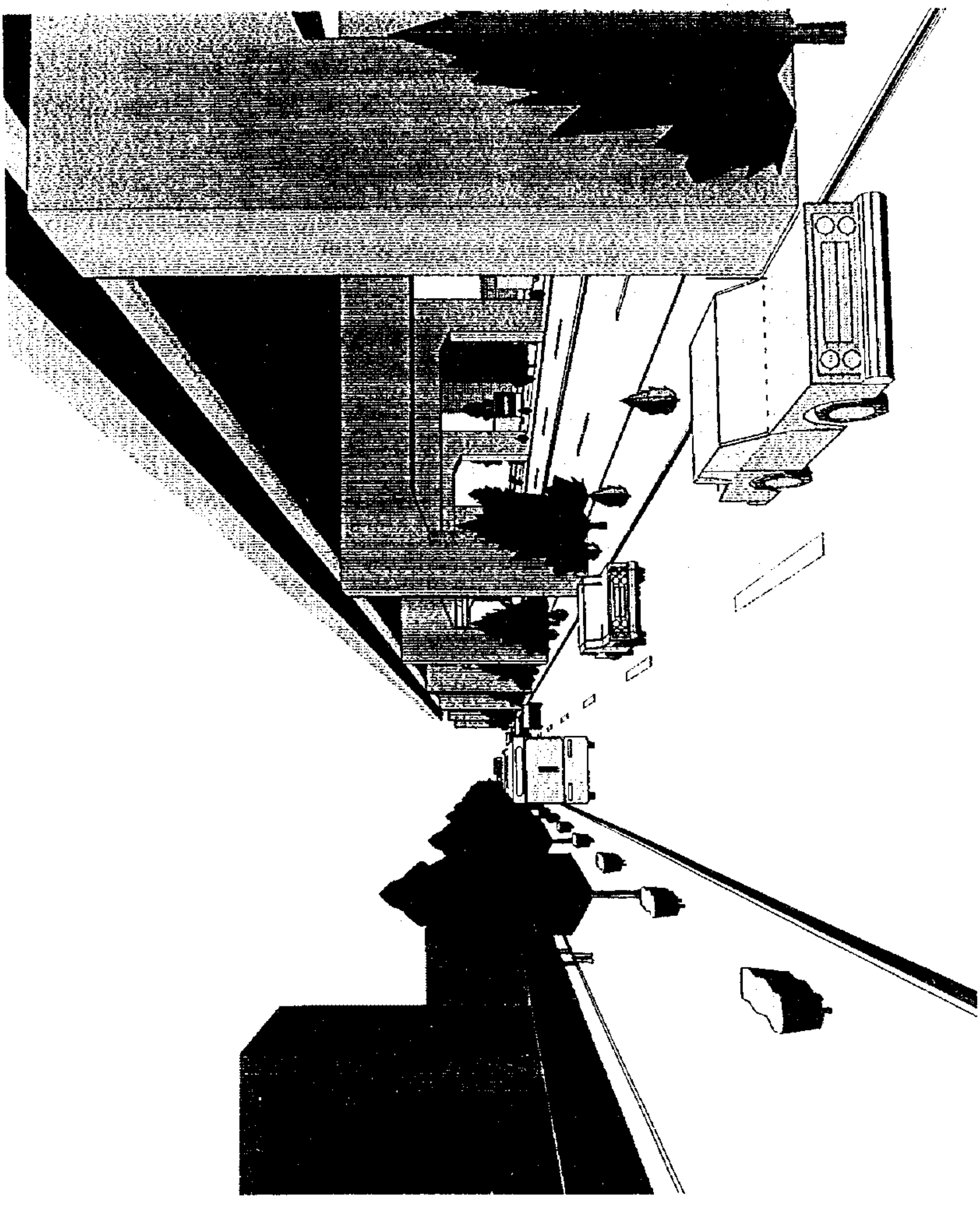


Figure 15.3-3 Three Dimension Plan of Alternative-A on Av.7a

15.3.2. ALIGNMENT ON CALLE 100 (SECTION BETWEEN AV. 7A AND CARRERA15)

(1) Horizontal Alignment

The typical road cross section of the existing Calle 100, at the segment between Avenida 7a and Carrera 15, is under the following conditions as shown in Figure 15.3-4.

1) 8-lane dual carriage way with 7.50 meters width of sidewalks on both sides.
2) 10 to 20 meters tall trees are planted on median and outside medians, at intervals of about 5 meters to 10 meters. There is also planting on the north-side of sidewalk.
3) The median width changes from 10 meters to 6 meters.
4) There are many tall buildings along the south-side of the Calle 100, and military school and housing are located on the north-side of road.

Considering the above road facilities conditions, the two (2) alternative alignment plans such as the Alternative-A and B are identified as shown in Figure 15.3-3. As a result of comparison study, Alternative-A is selected for alignment of IRE. The major reasons for the selection are as follows;

1) If either Alternative-A or Alternative-B will be constructed, the two lines of planting located on central and outside medians, should be demolished, however, Alternative-A requireds to demolish the planting on the central median only. From viewpoint the preservation of natural environment, Alternative-A is better than the Alternative-B.
2) When new trees will be planted on the south-side of sidewalk, the structure of IRE will be screened from the view of the inhabitants who are living along the Calle 100 by these trees.
3) From viewpoints of noise and air pollution, the Alternative-A is better than Alternative-B, because there will be about 20 meters space whereas between the IRE and the buildings which are located along Calle 100, Alternative-B provides less than 10 meters.

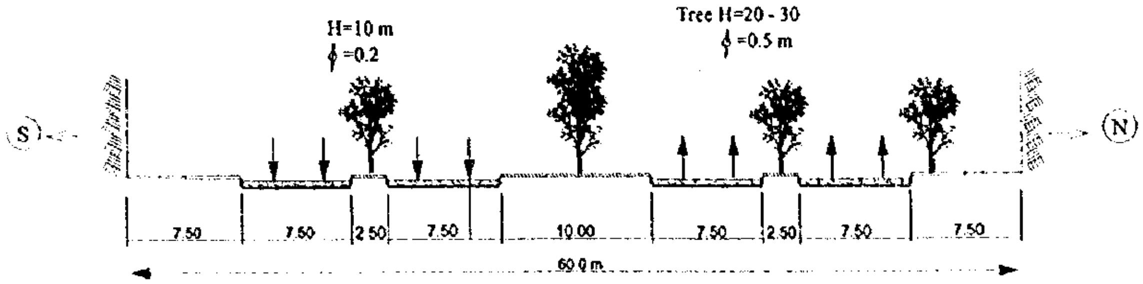
Figure 15.3-5 and Figure 15.3-6 show the plan of Alternative-A in manner of a stereoscopic 3-D view illustrating the layout.

(2) Vertical Alignment

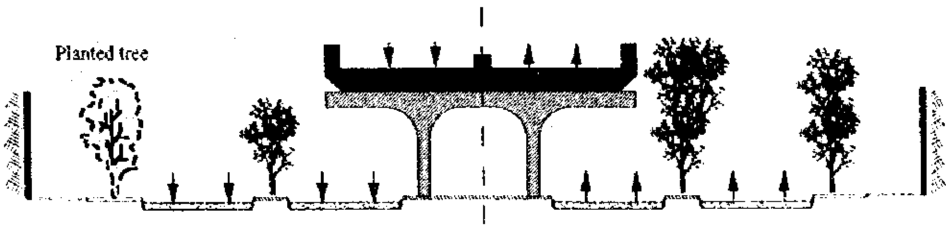
At present, there is no over-bridge and pedestrian bridge on the existing Calle 100 in the segment between Avenida 7a and Carrera 15. Considering the construction of a future pedestrian bridge under the same conditions of the Avenida 7a, the proposed height of IRE is identified at 11.0 meters over the existing pavement of Calle 100.

1. CALLE 100 (Section Av. 7a - Carrera 15)

(1). Existing Cross-Section



(2). Alternative - A



(3). Alternative - B

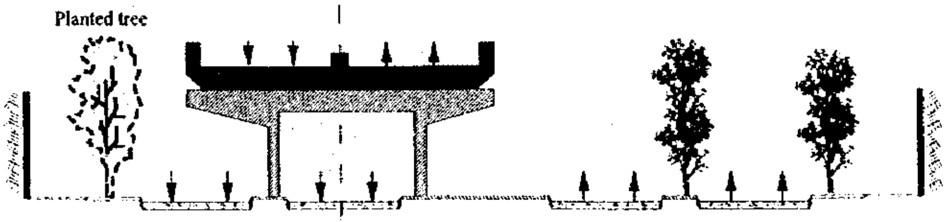


Figure 15.3-4 Location of Alternative Alignment Plan on Calle 100.

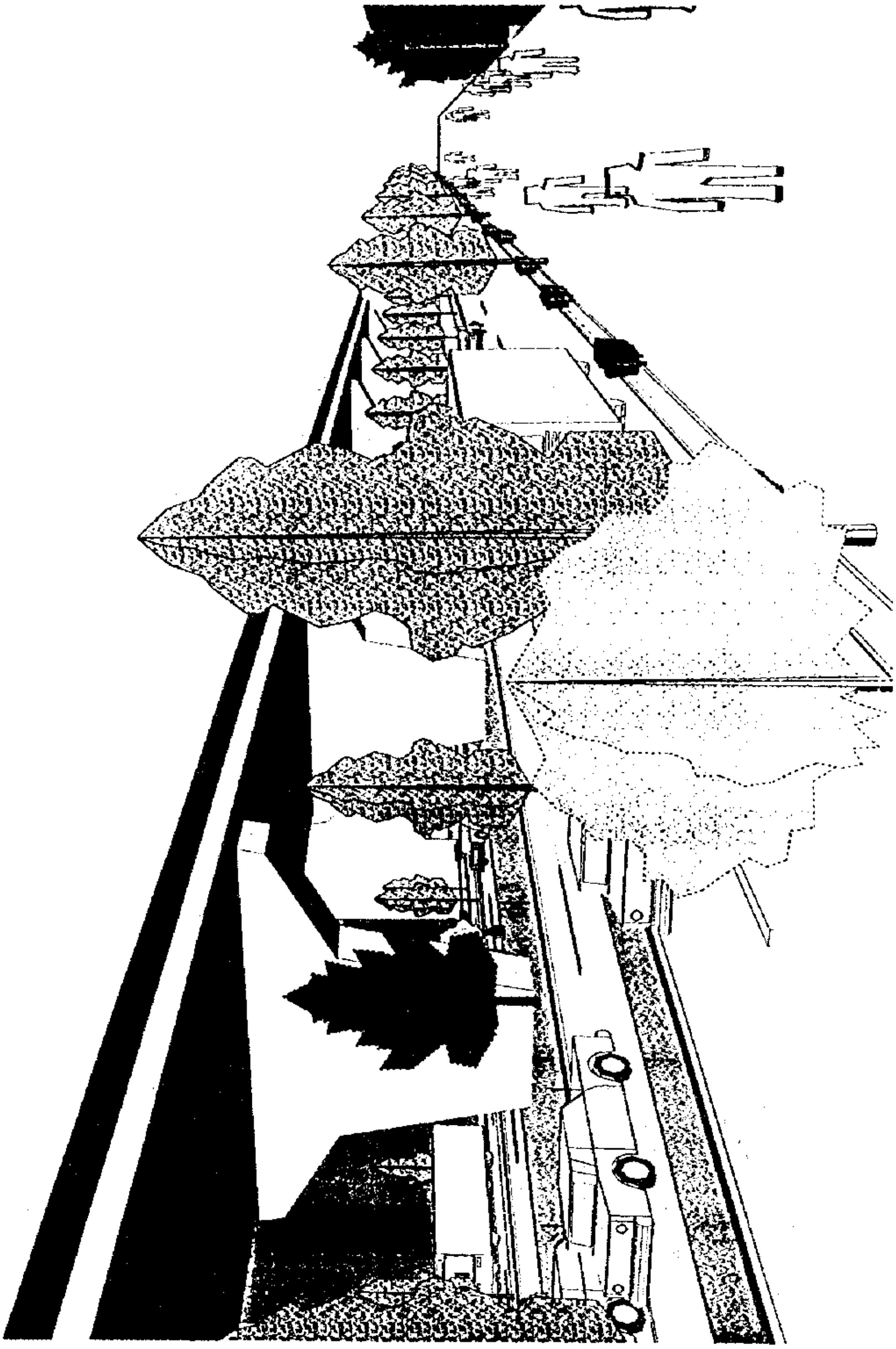


Figure 15.3-5 Three Dimension View of Alternative-A on Calle 100 (1)

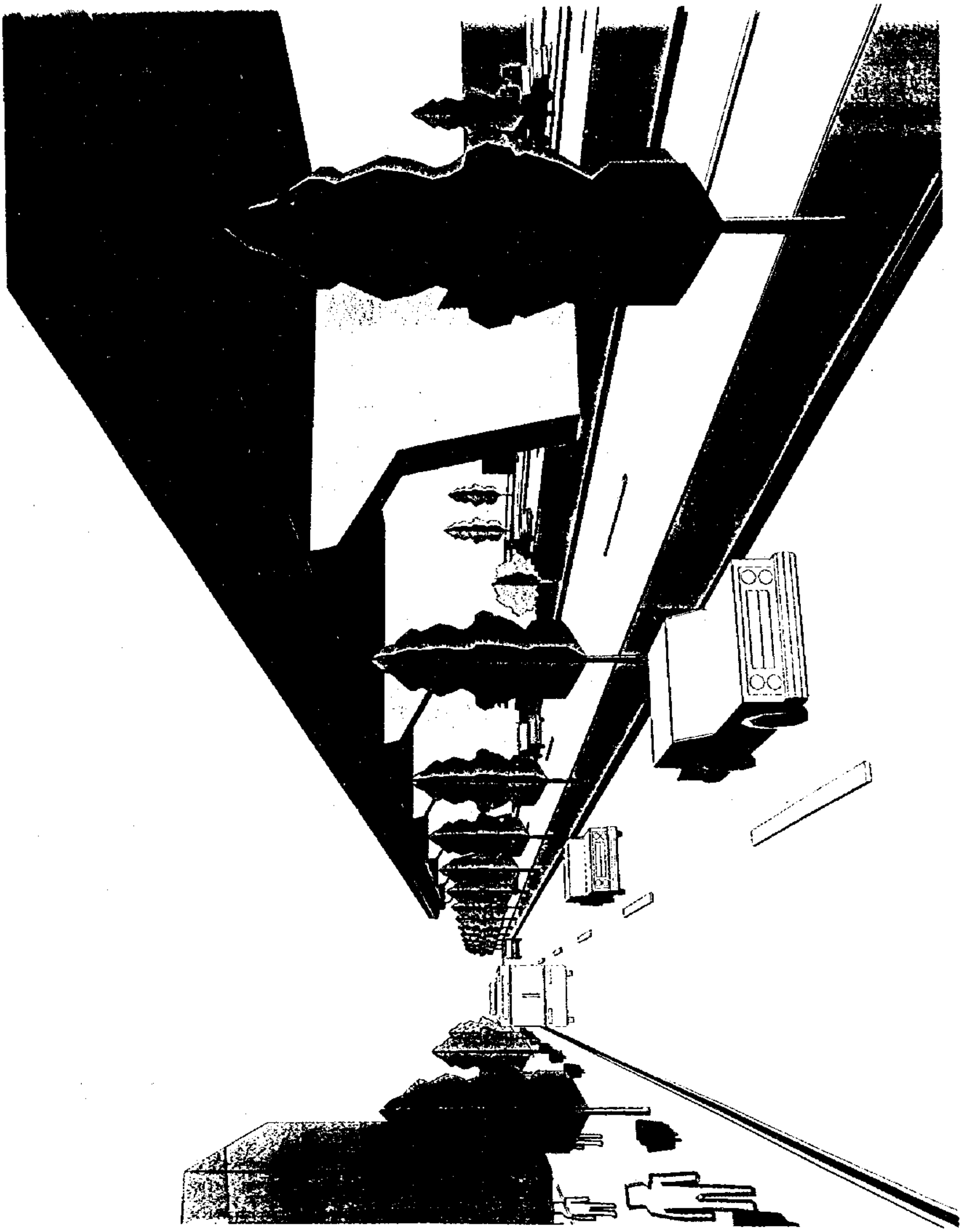


Figure 15.3-6 Three Dimension View of Alternative-A Plans on Calle 100 (2).

15.3.3. ALIGNMENT ON AVENIDA QUITO (SECTION BETWEEN CALLE100 AND CALLE68)

(1) Horizontal Alignment

The typical cross section of existing Avenida Quito at the segment between Calle 100 and Calle 68 is under the following facilities conditions as shown in Figure 15.3-7.

1) The right of way (ROW) varies between 50 meters to 68 meters, and the number of lanes also varies from 6-lane to 10-lane in both directions depending on the road segments..

2) At the center of the existing road, the railway runs on a single track The width of railway area varies from 15 meters to 24 meters. At present, there are no projections for the future, however, discussions of future plans (how to use the railway area) have just started between the central Government, Santa Fe de Bogota and related agencies.

3) According to the " Decreto Numero 317, Mayo 29 1992 ", the existing railway area will only be used for introduction of a public transport system.

4) In the Avenida Quito portion of this segment, there are a few planted areas in the railway area, however, the trees are very small.

5) Land use along existing road is almost all in housing, however, there are a few office buildings along the road. These housing and office buildings are constructed according to a set-back.

6) The 60 inches water pipe line is also constructed in the road area.

Considering the above mentioned facilities conditions, two (2) alternative plans for alignment of the Inner Ring Expressway such as Alternative-A and B as shown in Figure 15.3-7 are identified. As the result of comparison study between the two alternative plans, Alternative-B is selected, and the major reasons for selection are as follows;

1) The future development plan for the use the railway area is not decided yet, however, when the Inner Ring Expressway will be constructed in the railway area, other public transport systems will not be introduced in this area. Considering the importance of future public transport systems, the utilization of existing railway area is avoided in this study.

2) When trees will be planted on both sides of sidewalk, the Inner Ring Expressway will be screened from inhabitants living along the Avenida Quito. This is desirable from viewpoint of preservation of natural environmental aspects. The three dimension (3-D) section of Alternative-A is shown in Figure 15.3-8 and Figure 15.3-9.

(2) Vertical Alignment.

As mentioned previously in Section 15.2, there are many over-bridges and pedestrian bridges on the existing Avenida Quito, and the IRE should be passing above the existing over-bridges and pedestrian bridges. When the IRE is passing over the existing over-bridges, the proposed height of the IRE should be kept at 14.0 meters over the existing pavement height of Avenida Quito. The details of 14.0 meters needed are as follows:

1) Vertical clearance of vehicle on Avenida Quito........................4.5 m

2) Clearance for maintenance for Avenida Quito..........................0.5 m

3) Beam depth of over-bridge..2.0 m

4) Depth of pedestrian bridge: including above a), b), and c)
5) Vertical clearance for over-bridge .... 4.5 m
6) Clearance for maintenance of over-bridge .... 0.5 m
7) Beam depth of over-bridge .... 2.0 m
8) Total clearance needed... 14.0 m

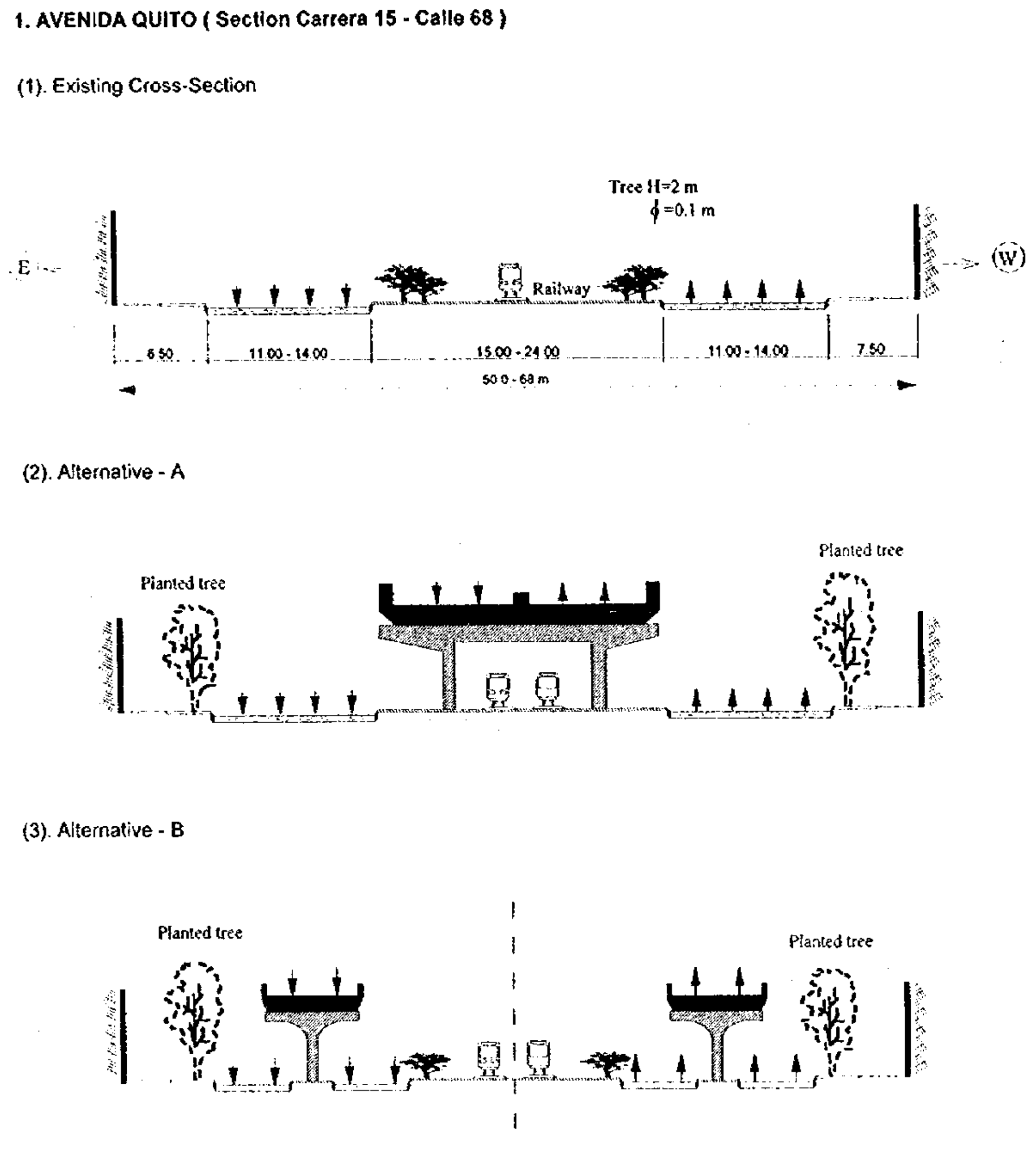


Figure 15.3-7 Location of Alternative Alignment Plan on Avenida Quito.

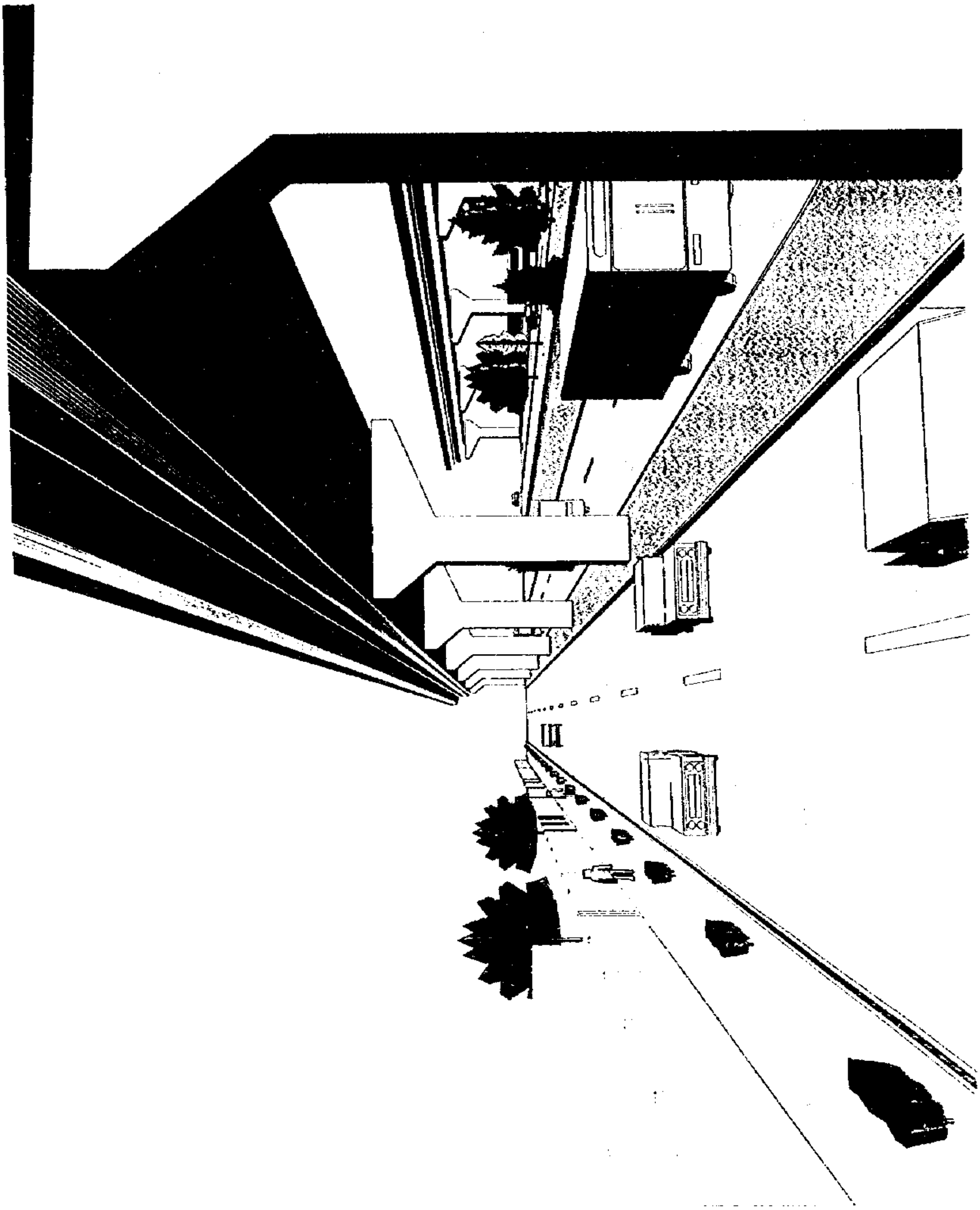


Figure 15.3-8 Three Dimension Plan of Alternative-B on Avenida Quito (1)

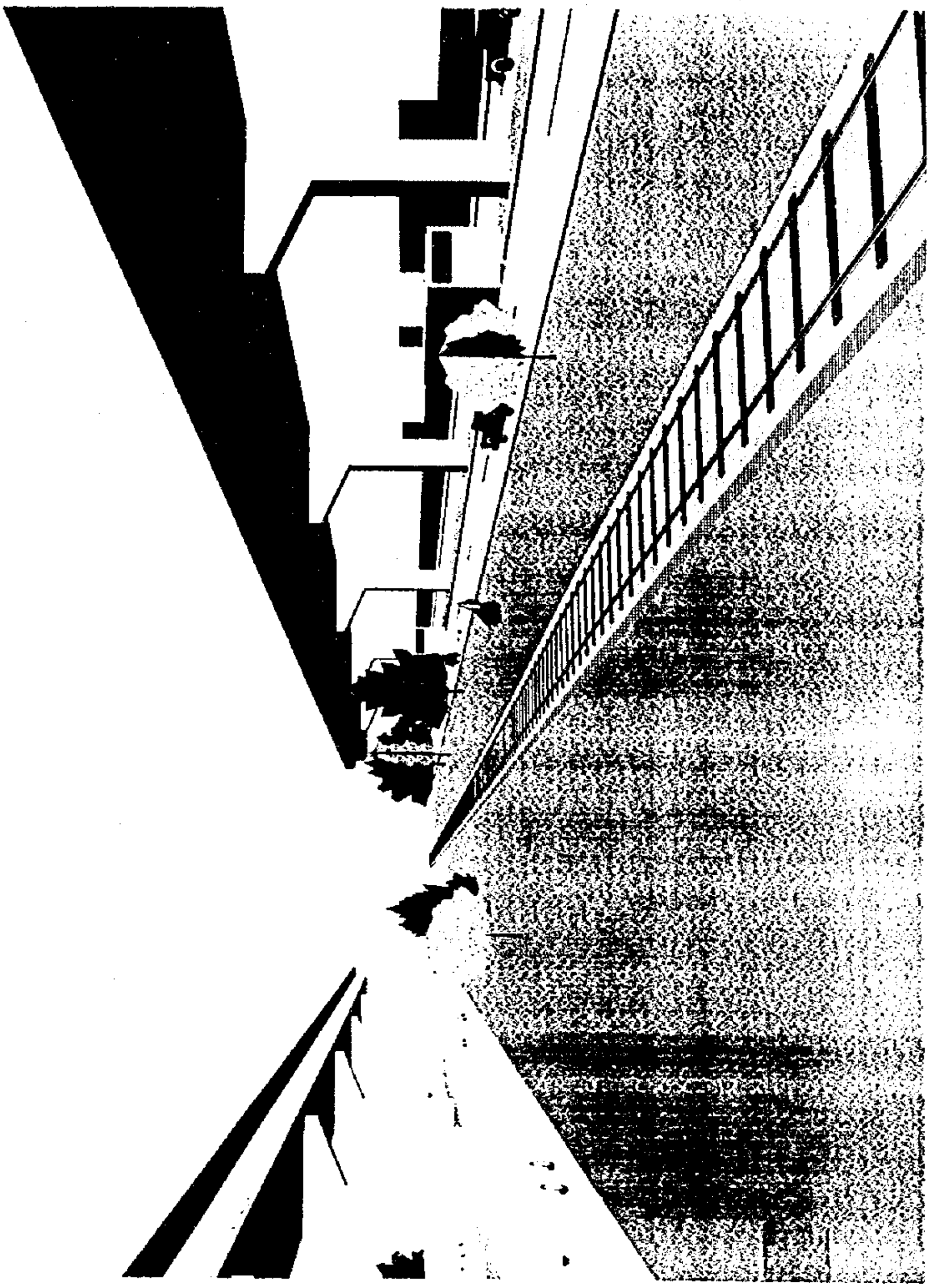


Figure 15.3-9 Three Dimension Plan of Alternative-A on Avenida Quito (2)

15.3.4. ALIGNMENT ON AVENIDA QUITO (SECTION BETWEEN CALLE 68 AND CALL 51)

(1) Horizontal Alignment

The typical cross section of the existing Avenida Quito, of the road segment between Calle 68 and Calle 51, is under the following facilities conditions as shown in Figure 15.3-10.

1) The three lines of road plantatings are provided on the central median and on both sides of canal, and these trees are about 10 to 20 meters tall.
2) The right of way (ROW) width is about 66 meters to 68 meters with 6-lane for passing through lanes and 4-lane for frontage roads.
3) The width of sidewalks is about 3.5 meters of both road sides.
4) The electric power line is located on the outside median.
5) There is a canal with 15 to 18 meters width at the west side of the through lane.

Considering the above mentioned facilities, three (3) alternative plans for location of horizontal alignment, Alternative-A, B, and C are shown in Figure 15.3-10. As the result of comparative study, Alternative-B is selected. The three-dimension section of Alternative-B is shown in Figure 15.3-11 and Figure 15.3-12, and the photo montage of the Alternative-B is shown in Figure 15.3-13 for easy understanding of the IRE. The major reasons for selection of alternatives are as follows;

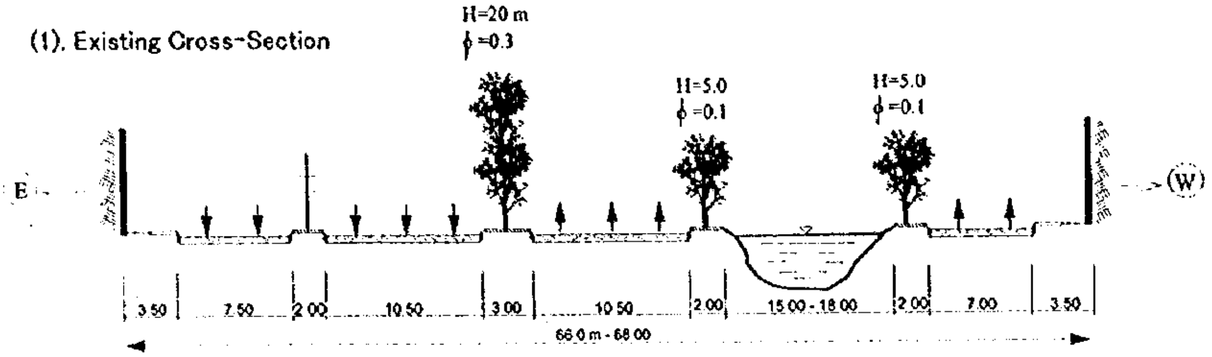
1) From viewpoints of landscape aspects, Alternative-A provides a large open space (about 20 meters on both sides) from the housing or office buildings unlike the other alternatives.
2) From viewpoints of the preservation of natural environmental aspects, the trees on median should be demolished under Alternative-A. However, re-planting of the trees at the outside median should take place, then the IRE will be screened by these re-planted trees.
3) From viewpoints of noise protection conditions, Alternative-A is better than the other alternatives because there will be wide space between the buildings which are located along the Avenida Quito and the IRE.

(2) Vertical Alignment

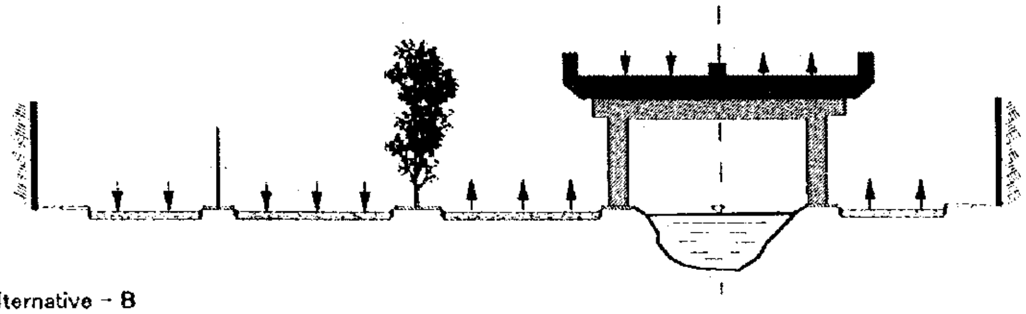
The vertical alignment is adopted following the same conditions as the previous segment on Avenida Quito.

4. AVENIDA QUITO (Section Calle 68 - Calle 51)

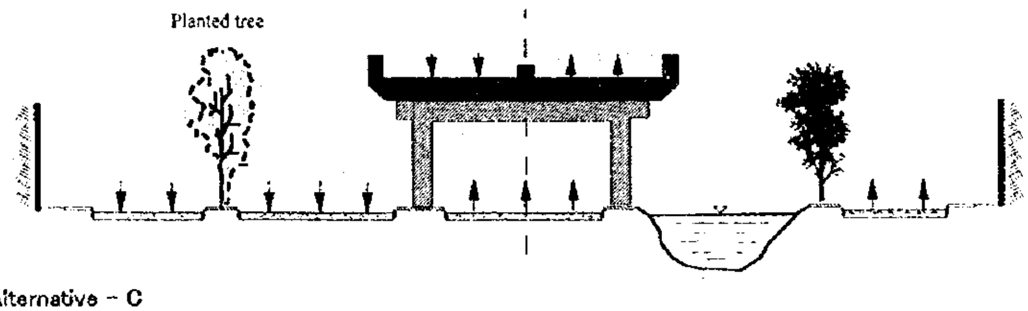
(1). Existing Cross-Section



(2). Alternative - A



(3). Alternative - B



(4). Alternative - C

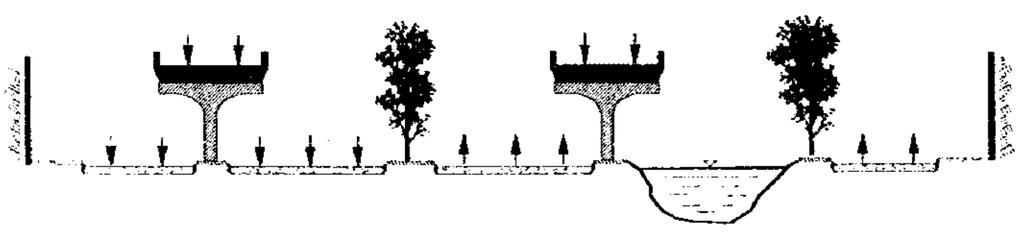


Figure 15.3-10 Location of Alternative Alignment Plans on Avenida Quito

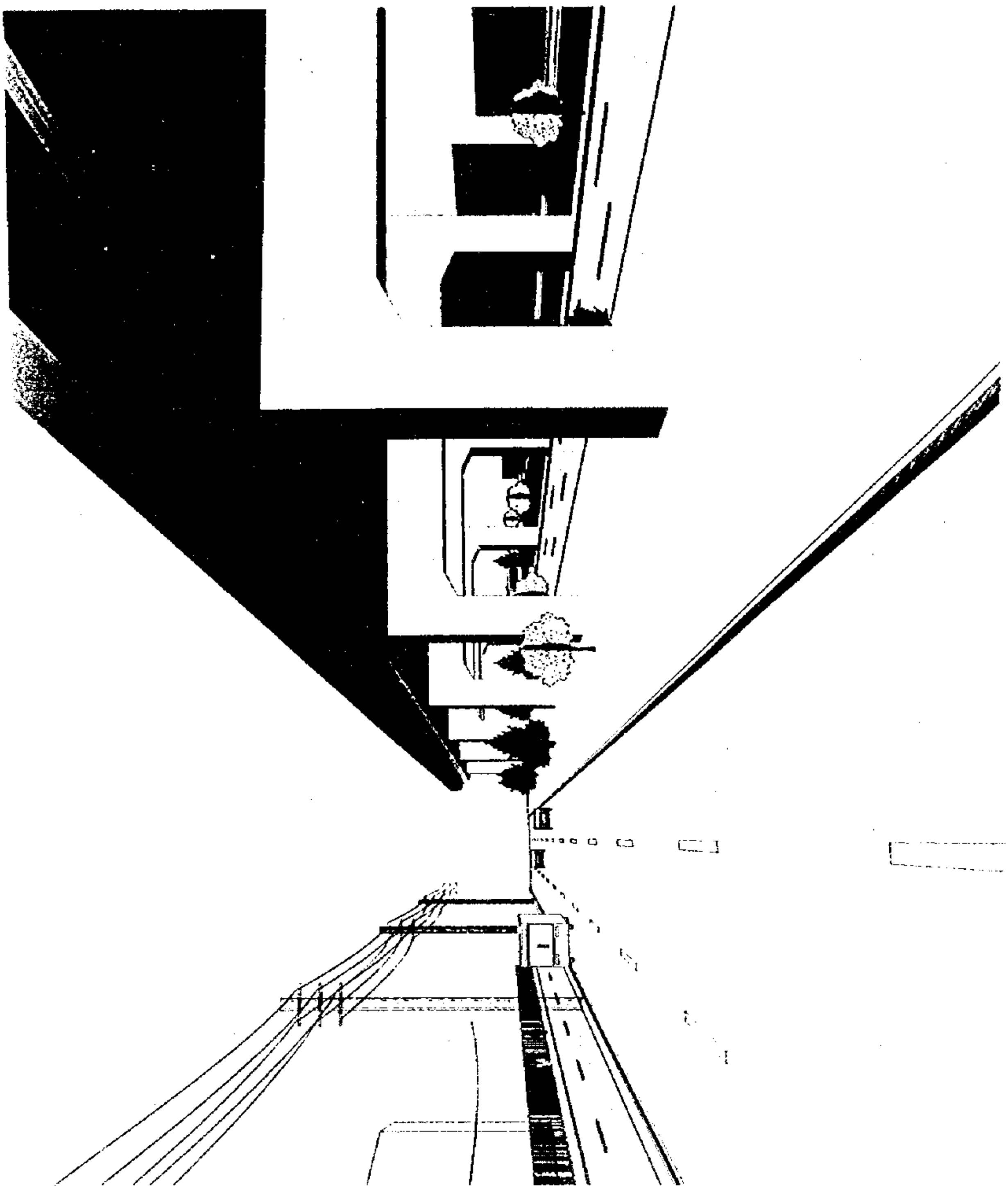


Figure 15.3-11 Three Dimension Plan of Alternative-B on Av. Quito (1)

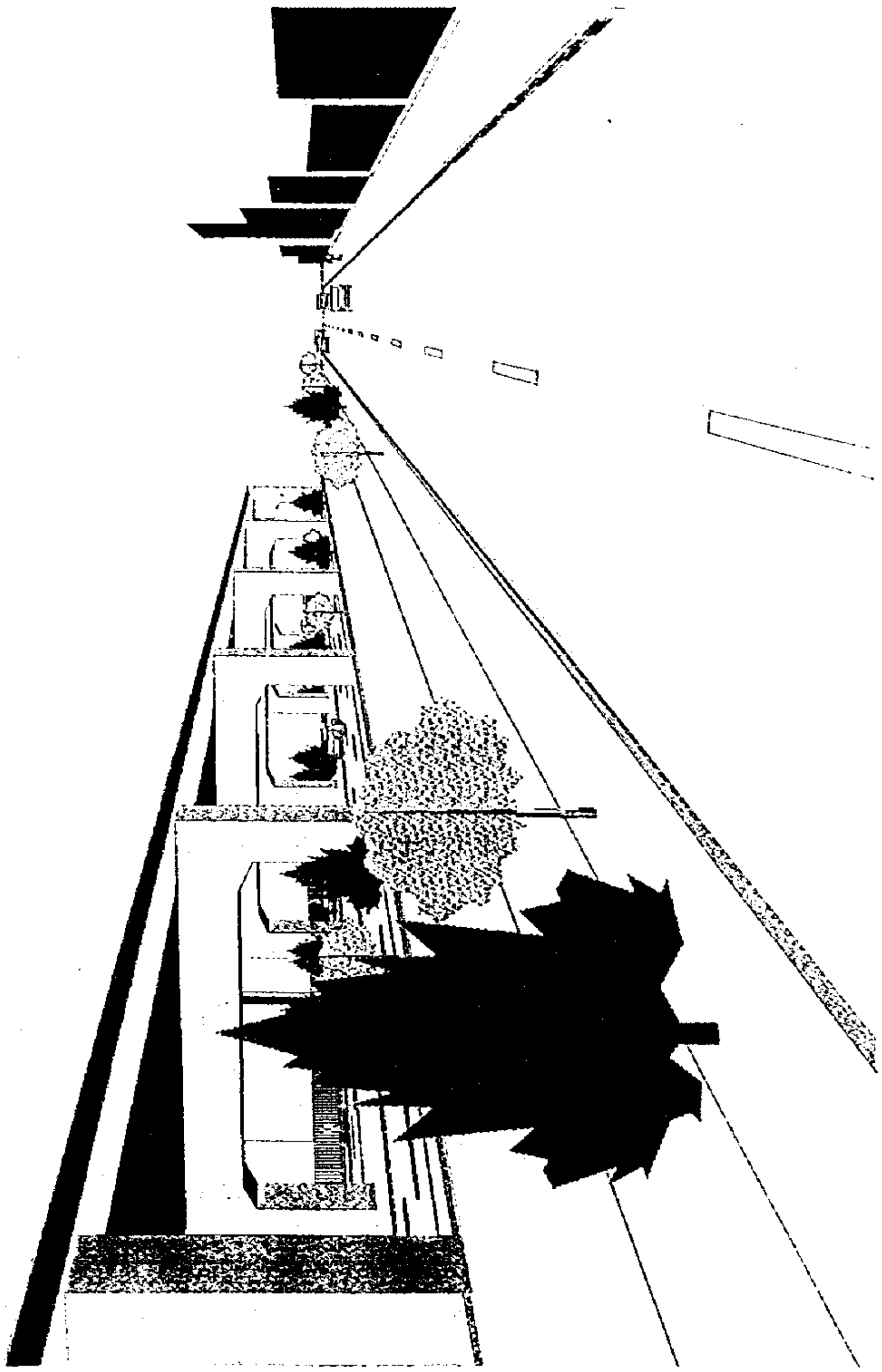
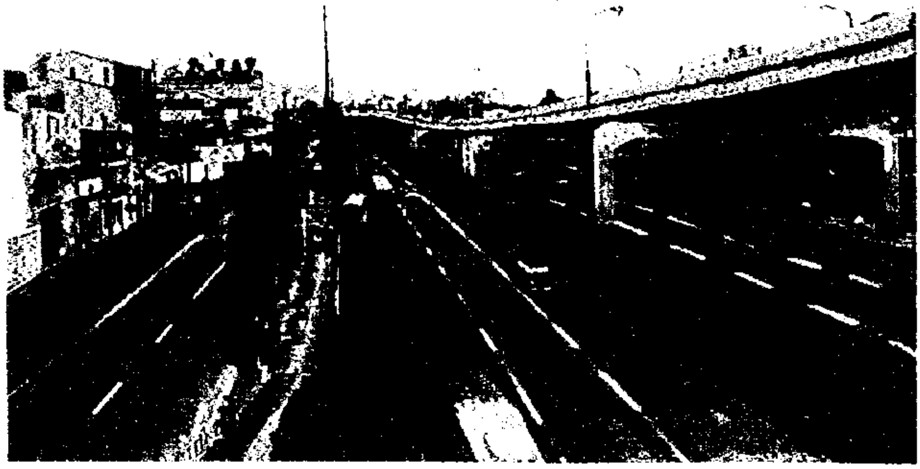


Figure 15.3-12 Three Dimension Plan of Alternative-B on Av. Quito (2)



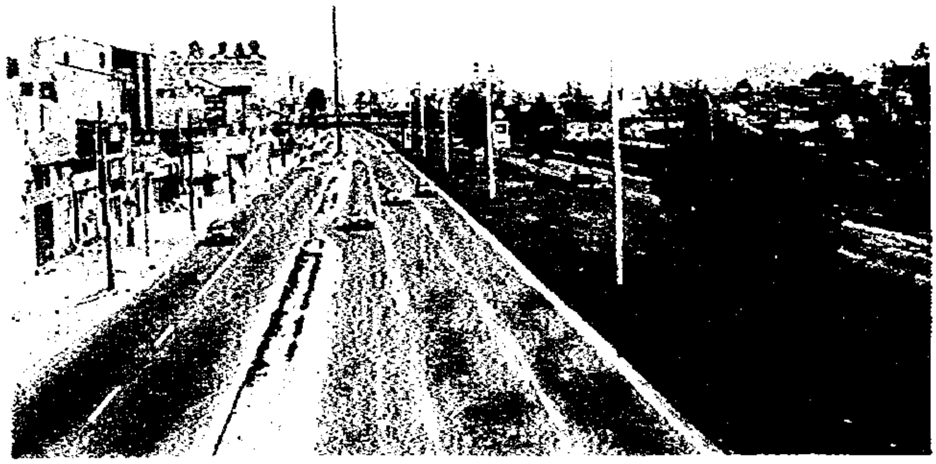


Figure 15.3-13 Photo Montage of Alternative-B on Av. Quito

15.3.5. ALIGNMENT ON AVENIDA QUITO (SECTION BETWEEN CALLE51 AND CALLE 6)

(1) Horizontal Alignment.

The typical cross section of existing Avenida Quito on the segment between Calle 51 and Calle 6 is under the following road facilities as shown in Figure 15.3-14.

1) The 50 meter right of way with 6-lanes for passing through lanes and 4-lanes for frontage roads on both sides are provided. 3.5 meters sidewalks on both sides of the road are also constructed.

2) 3.0 meters on central median and 2.0 meters on outside medians are provided.

3) About 15 meters tall trees on the central median and about 10 meters tall trees on outside median are provided.

4) d) There are many mixed buildings, commercial and housing, on the east side of the existing road, and many institutional buildings such as National University and National Land Office are located on the west side of the road. The CAD office of Bogota municipality and hospital are located on the east side of the road.

Taking into account the above mentioned facilities, the two (2) alternative alignment plans such as Alternative-A and B are prepared as shown in Figure 15.3-14. As the result of comparison study, Alternative-A is selected for the IRE, and the three dimension views of Alternative-A are shown in Figure 15.3-15 and Figure 15.3-16, and the photo montage views are shown in Figure 15.3-17 and Figure 15.3-18 for easy understanding of the IRE. The major reasons for selecting Alternative-A are described below:

1) From viewpoints of the preservation of natural environmental aspects, the Alternative -B is better than the Alternative-A, however, considering noise problems for inhabitants living along the road, the Alternative-A is better than the Alternative-B because Alternative-A can provide more wide open space (about 15 meters) between the IRE and the buildings which are located along the road.

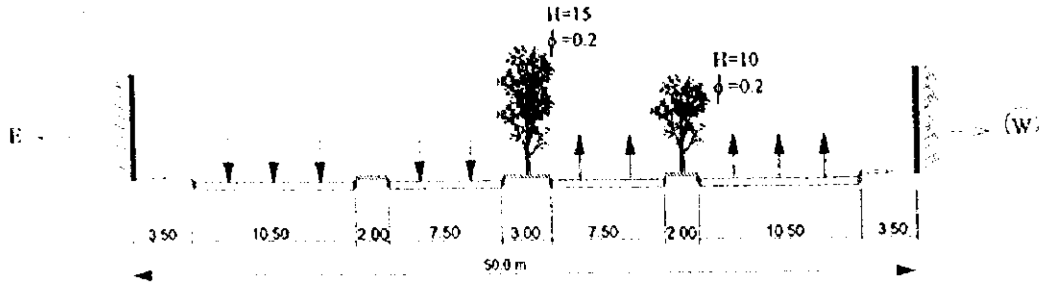
2) Under Alternative-A, road-side trees on both sides on the outside median can be provided for use in open space between the piers of the viaduct. The IRE can be screened by these trees from the buildings, which are located along the road.

(2) Vertical Alignment

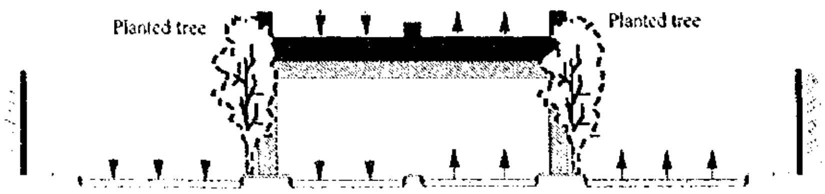
The vertical alignment is adopted following the same conditions as the previous segment on Avenida Quito.

5. AVENIDA QUITO (Section Calle 51 - Calle 6)

(1). Existing Cross-Section



(2). Alternative - A



(3). Alternative - B

Figure 15.3-14 Location of Alternative Alignment Plans on Avenida Quito.

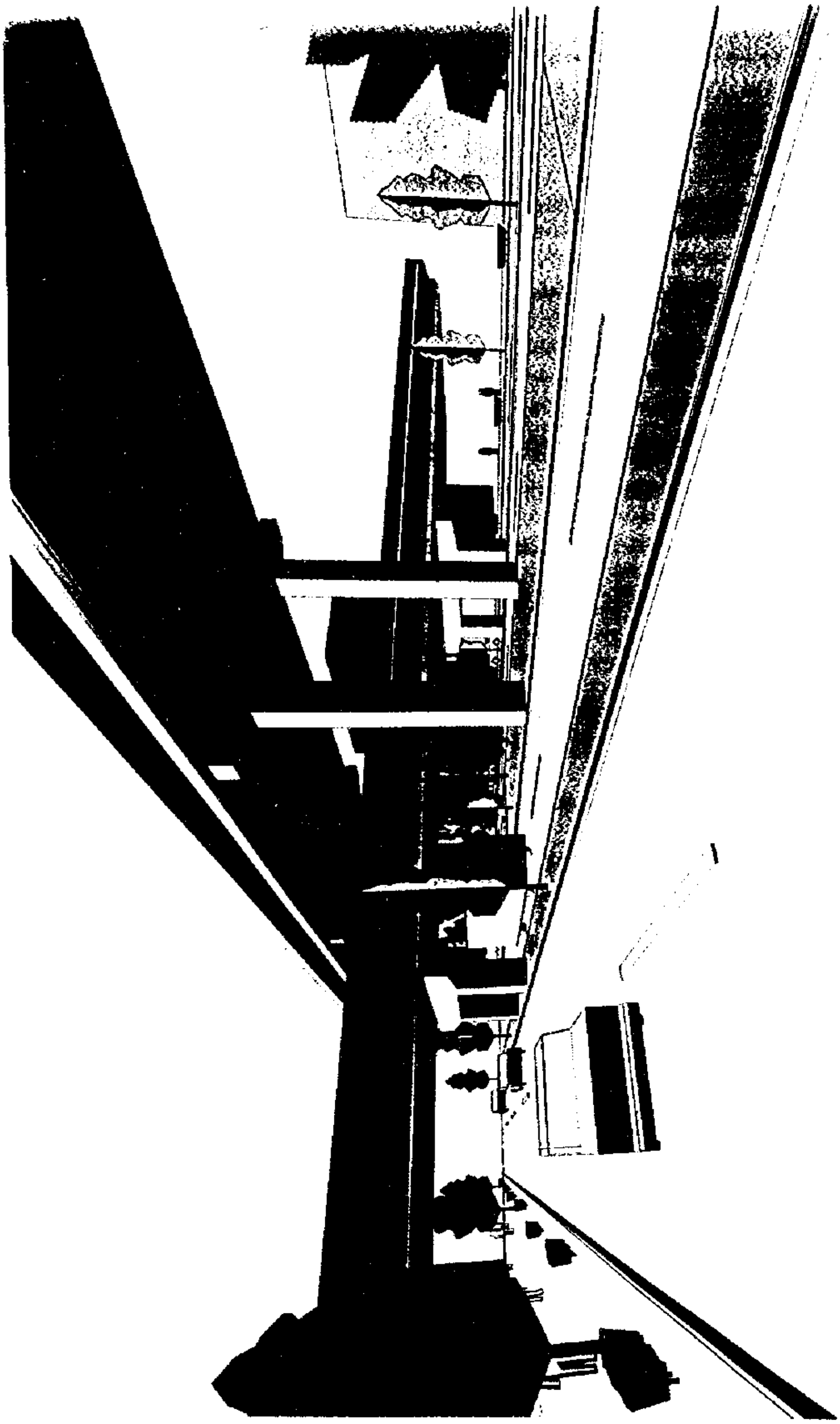


Figure 15.3-15 Three-Dimension Plan of Alternative-A (1)

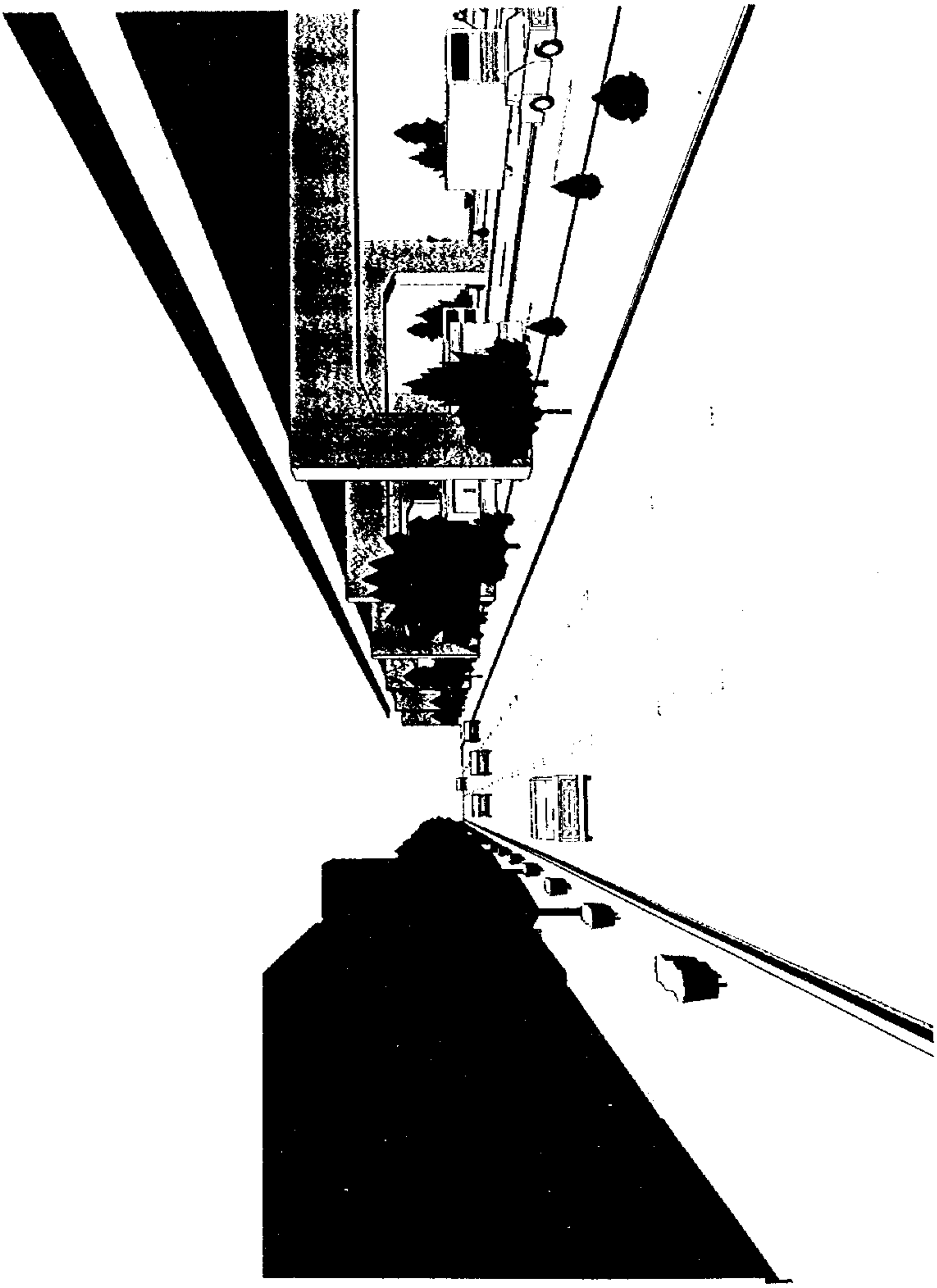


Figure 15.3-16 Three-Dimension Plan of Alternative-A (2)

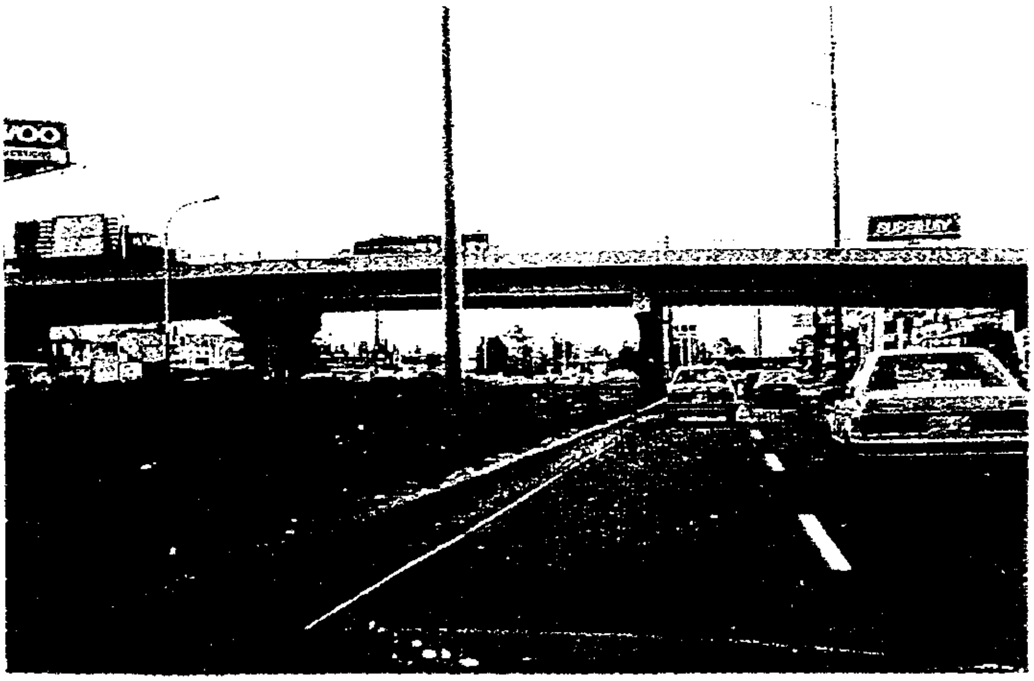


Figure 15.3-17 PhotoMontage of Alternative -A (1)

Figure 15.3-18 PhotoMontage of Alternative-A (2)

15.3.6. ALIGNMENT ON CALLE 6 (SECTION BETWEEN AV. QUITO AND AV. CARACAS)

(1) Horizontal Alignment

The typical cross section of the existing Calle 6 on segment between Avenida Quito and Avenida Caracas is under the following road facilities conditions as shown in Figure 15.3-19.

1) The 60 meter right of way with 8-lane carriage way is provided, which includes 4.5 meter sidewalk on both sides.
2) In the center of road, an 18 meters wide canal is located.
3) On both sides of embankment of the canal, about 20 meters tall trees are provided.
4) Land use of south side of the road is classified as industrial and mixed use areas. On the north side of the road it is classified as housing areas.

Taking into account the above-mentioned facilities, two alternative alignment plans such as Alternative-A and B are identified. As the results of comparison study, Alternative-A is selected for the IRE. The three-dimension section of Alternative-A is shown in Figure 15.3-20. The major reasons for the selection are described below:

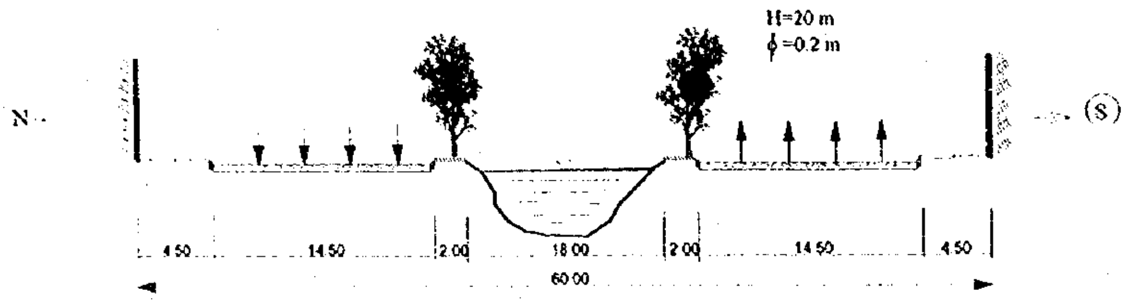
1) There are two lines of the plantatings (about 20 meters tall trees) on both embankments of the canals. These should be removed when the alternatives will be constructed. However, new trees can be planted at both sidewalks on Alternative-A, and the IRE may be screened by newly planted trees.
2) Alternative-A can provide 20 meters of open space from the edge of the IRE and screen the commercial and housing buildings which are located along the Calle 6.
3) Obviously, the construction cost of Alternative-A is cheaper than the Alternative-B, and the construction magnitude of Alternative-A will not be extensive.

(2) Vertical Alignment

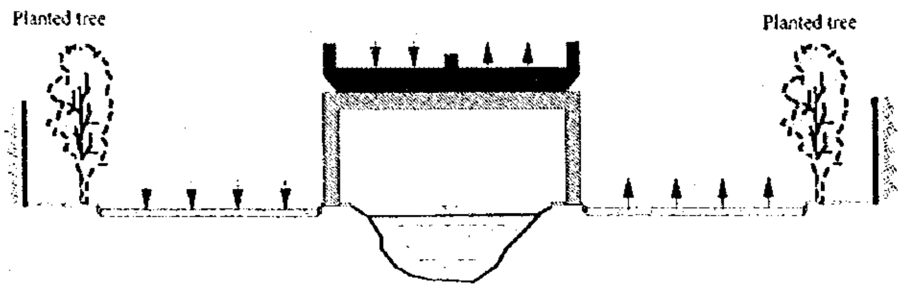
The proposed height on the intersection of Avenida Quito is maintained at 14.0 meters clearance from the existing pavement height of road because there is a plan for grade separation at this intersection. The clearance of the other segment is adopted at 11.0 meters.

1. CALLE 6 (Avenida Quito - Avenida Caracas)

(1). Existing Cross-Section



(2). Alternative - A



(3). Alternative - B

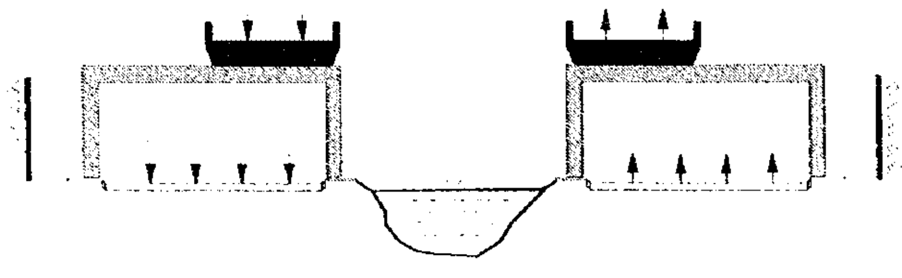


Figure 15.3-19 Location of Alternative Alignment Plan on Calle 6.

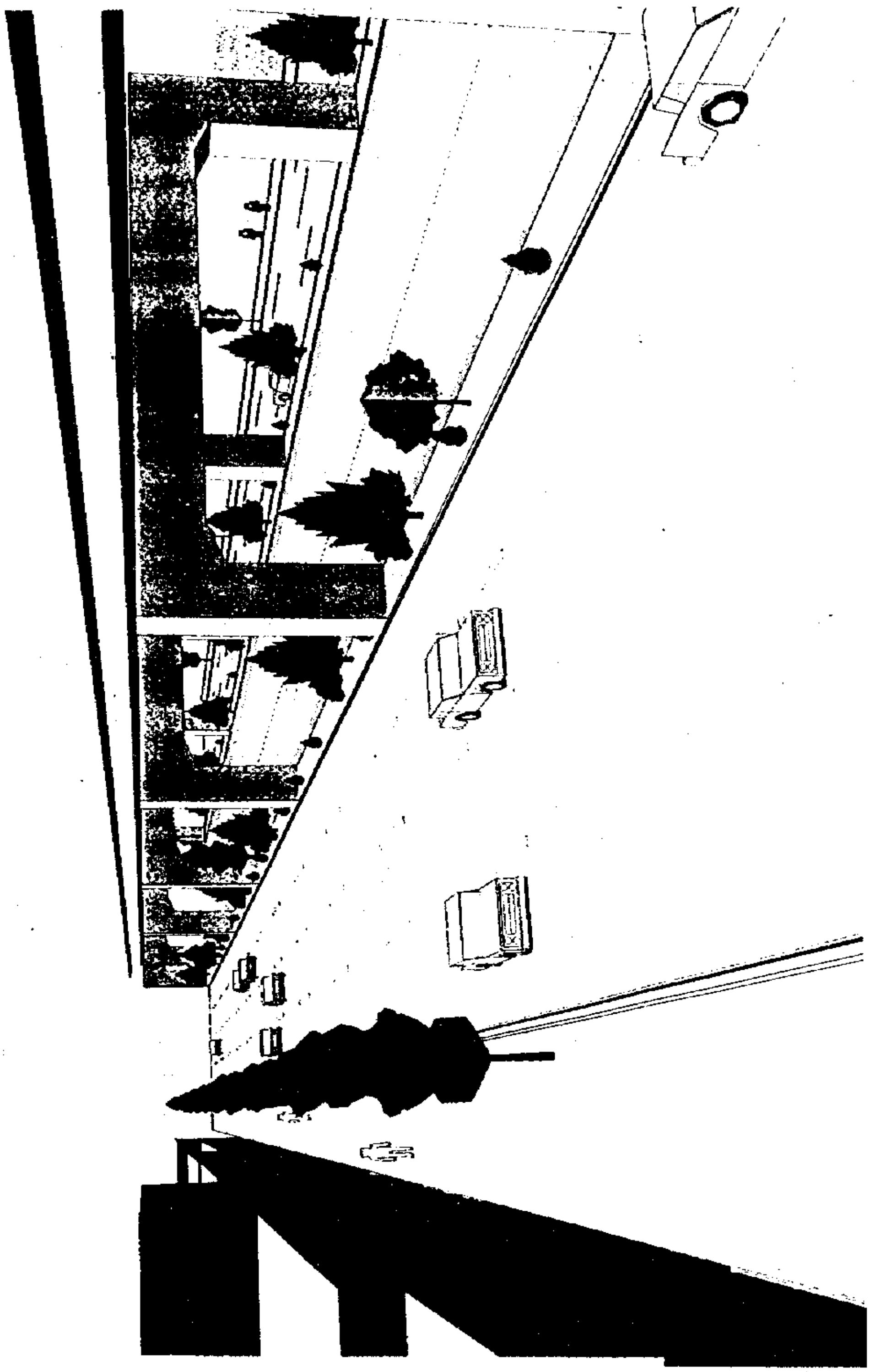


Figure 15.3-20 Three-Dimension Section of Alternative-A

15.4. CROSS SECTION DESIGN.

15.4.1. NUMBER OF LANES REQUIRED

In previous section 13 in this Report, the future traffic demand in 2015 was forecast based on the person trip survey conducted by JICA Study Team in 1995 to 1996. The IRE will be operated to introduce the toll road system considering the Government budget conditions and burden share by the beneficiary users of the IRE.

As mentioned previously, the future traffic volume is changed in accordance with the traffic toll charge such as 2,000 pesos and 3,000 pesos. The optimum toll charge will be decided after examination of the financial study, and the existing toll road conditions of Bogota. There are many toll roads inside or near the city of Bogota, and the toll charge on each road is decided in accordance with the size of vehicles as follows,

1) Autopista Norte..2,200, 2,600, to 10,000 pesos
2) Autopista Medellin....................................3,100, 3,900, to 13,700 pesos
3) Autopista Sur..2,100, 2,400, to 10,000 pesos
4) Avenida La Carera....................................2,900, 4,700, 3,200, to 14,900 pesos
5) Road between Soacha and Mosquera........2,100, 2,400, to 10,000 pesos
6) Road between Mosquera and Cota............2,100, 2,400, to 9,600 pesos
7) Avenida 7a..2,200, 2,600, to 10,100 pesos

Considering the toll charge under the existing conditions, the number of lanes required for the IRE is decided based on the future traffic volume in 2015 with 3,000 pesos toll charge. The future traffic volume in 2015 on each road segment of the IRE is shown in Table 15.4-1. The number of lanes required is decided in comparison between future traffic volume and the traffic capacity of the IRE. The traffic capacity is estimated at about 15,000 pcu/d per lane considering the road facilities conditions of the IRE, and the number of lanes required and shown in Table 15.4-1. As a result of comparison, Calle 6 is required as 2-lane road, however, considering the function and characteristics of the IRE, the number of lanes required is adopted as 4-lane dual carriageway, with 2 lanes for the general vehicles and the other 2 lanes for bus express.

Table 15.4-1 Number of Lane Required on Inner Ring Expressway

Road Segment	Future Traffic Volume(pcu/d) (A)	Traffic Capacity (pcu/d/lane) (B)	No. of lane required (A/B)	Remarks
On Av. 7a (Call116to Calle100)	33,000	15,000	4	
On Call 100 (Av.7a to Av,15)	46,000	15,000	4	
On Av. Quito (Av.15 to Calle63)	46,000	15,000	4	
On Av. Quito (Calle 63 to Call6)	48,000	15,000	4	
On Calle 6 (Av. Quito to Av. Caracas)	19,000	15,000	4 (2)	

15.4.2. CROSS SECTION ELEMENTS

The cross section element is examined taking into account the following items.

1) Road structure type....................................Viaduct type

2) Traffic characteristics .... Only vehicles

3) Running speed...................................... 60 km/h to 80 km/h

The following elements for road segment and on/off ramp ways are adopted for this study as shown in Table 15.4-2. The typical cross sections of road way and ramp way are shown in Figure 15.4-1 and Figure 15.4-2, respectively.

Table 15.4-2 Cross Section Elements Adopted

Items	Unit	Road Way	Ramp Way	Remarks
No. of lane	No.	4-lane dual	2-lane dual	
Carriageway Width	m	3.5	3.5	
Lateral clearance(left)	m	1.25	0.75	
Lateral clearance (right)	m	0.75	0.5	
Superelevation	%	2	2	
Median width	m	1.0	0	
Road way width	m			

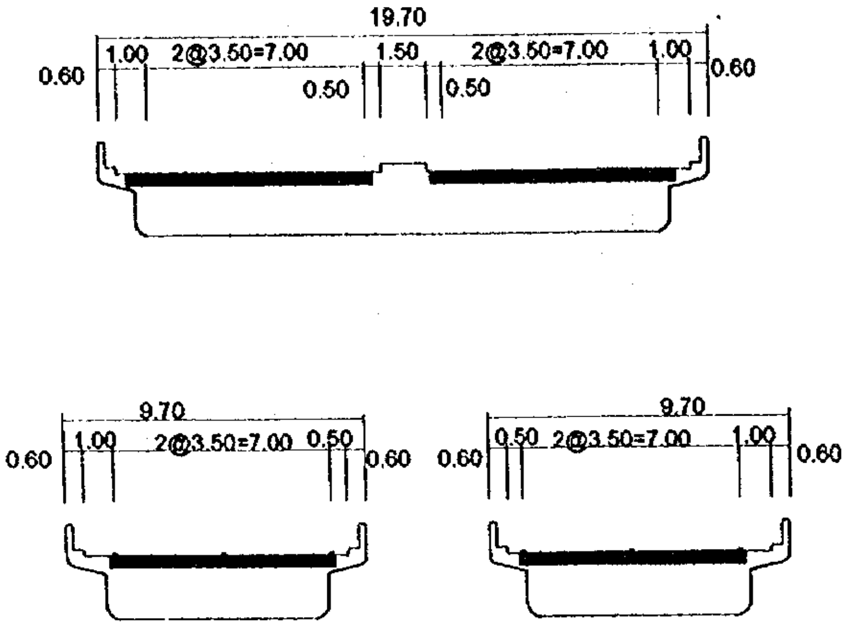


Figure 15.4-1 Typical Cross Section of Road Way

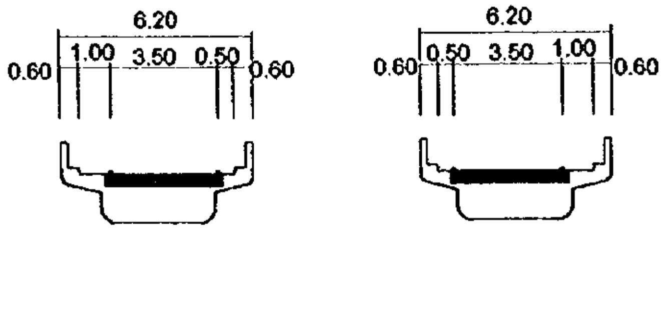


Figure 15.4-2 Typical Cross Section of Ramp Way

15.5. BRIDGE DESIGN

15.5.1. DESIGN BACKGROUND

(1) Existing Bridge

In Bogota City, many flyover bridges have been built at main junctions. The types of these bridges are cast-in-situ concrete girder, PC concrete girder, steel box girder etc. Those, which were built recently, are PC bridges. Steel bridges are not being used due to high cost, since materials have to be imported. There are no iron works in the city and regular maintenance such as re-painting is required.

Many pedestrian bridges have also been built. The types of these bridges are concrete girder bridge, truss bridge, steel arch bridge cable-stayed bridge etc. Pedestrian bridges built recently are designed to suit specific conditions.

Ground condition of Bogota City is very soft except for East Hill side and settlement on approaches of the existing bridges is observed in some areas. Extensive soil improvement work for soft ground is not generally undertaken in connection with existing bridge construction. Therefore, proper counter measure is required for soft ground at the time of bridge planning.

The existing bridge columns appear to be slim, however, in 1995, a regulation for anti-seismic design was established by The Road Department in the Ministry of Transport. As a result, durability against seismic energy is being improved for new bridge construction.

(2) Sub-Surface Soil Condition

Bogota City is located in a basin, which was marshland originally. Soft soil was deposited deep below the ground surface. Sand stone is exposed at ground surface at Eastern Hill. Sand stone can be observed at relatively shallow depths, shallower than 30m, between Avenida 7a and Avenida Caracas. Sand stone, as foundation bed, is not observed even at depth more than 100m at Western side from Avenida Cararas, and no firm layer, as bearing strata, can be observed.

Ground condition of Bogota City is classified into the following three zones;

1) Area where sand rock, as foundation bed, is exposed: Eastern Hill from Avenida 7a

2) Area where sand rock, as foundation bed, can be observed at depths shallower than 30m: Between Avenida 7a and Avenida Caracas

3) Area where soft soil is continuing and bearing strata can not be confirmed: Western side from Avenida Cararas

Geological cross section of Bogota City is as shown in Figure 15.5-1.

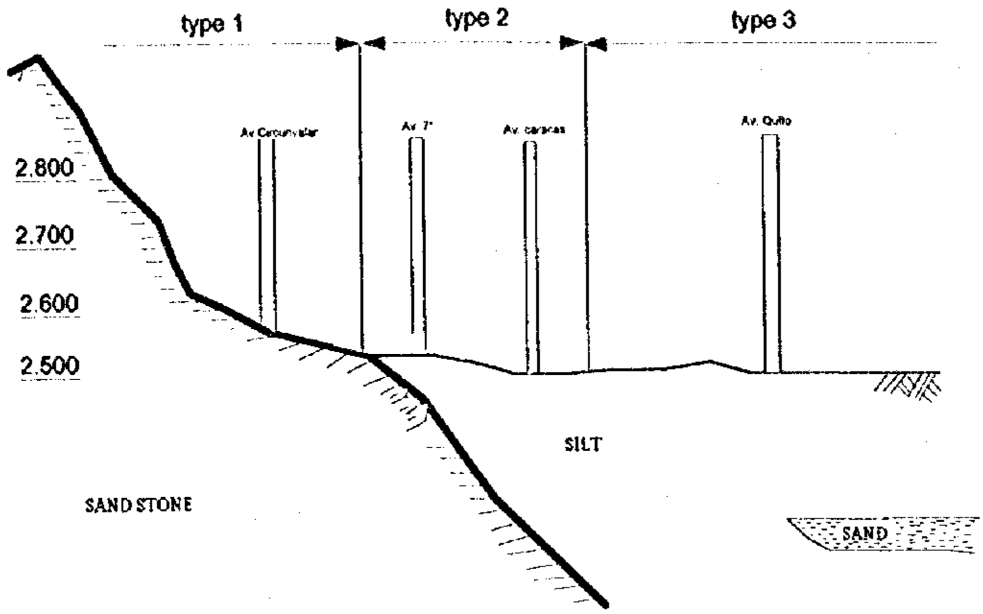


Figure 15.5-1 Geological Cross Section of Bogota City

(3) Procurement of Materials

Major materials used for construction are cement, aggregates, reinforcing bar, PC wire and steel such as steel plate and section steel. Cement can be procured 100% in Bogota City and good quality aggregates are also available. High quality of ready mixed concrete is being delivered to any place in the city. The same as cement, reinforcing bars are also produced and delivered in the country.

Steel such as PC wire, steel plate and section steel has to be imported due to non existence of steel mill in the country.

(4) Technical Capability

Already various type of bridges such as reinforced concrete bridges, PC bridges, and steel bridges have been built in Bogota City; technical capability for bridge construction is considered at a high level. There are several bridge consultants and contractors and many experienced and qualified engineers are engaged in such work. The existing structures have been built following AASHTO which is the American Standards however, national standards and specifications were established recently.

Bridge construction technique available in the country is sufficient to meet the requirements of bridge type and structure in this study and no problem is envisaged.

15.5.2. Design Criteria

(1) Design Standards

Instituto Nacional de Vias established its own standards (Codigo Colombiano de Diseno Sismico de Puentes) in 1995. This study basically follows this standard. This standard is based on AASHTO and modified to the specific live load and seismic load in Colombia.

(2) Live Load

Live load used for road structure design in Colombia is specified in the Codogo Colombiano de Diseno Sismico de Puentes. In this study, design is made based on this live load basically and because it is the most important structure in the capital area, the heaviest live load of C40-95 (Figure 15.5-2) is applied.

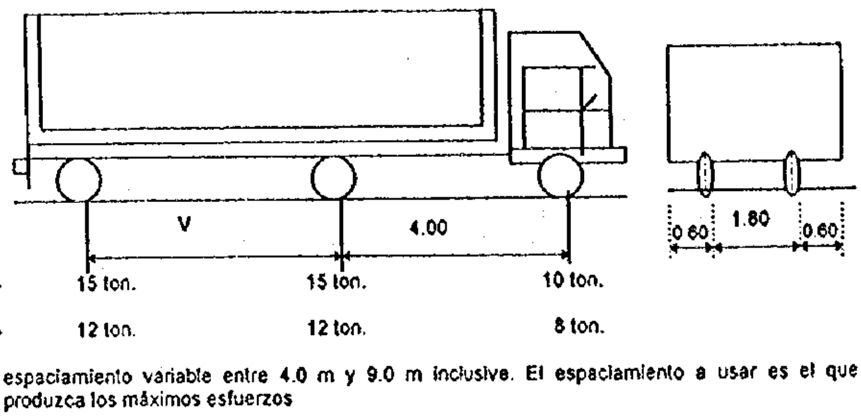


Figure 15.5-2 Live Load (C40-95)

Track Clearance of bridge is the horizontal road width and 4.5m vertically as shown in Figure 15.5-3.

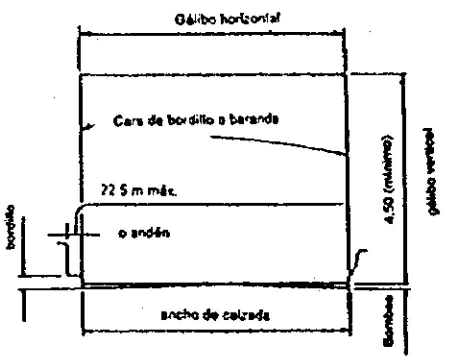


Figure 15.5-3 Truck Clearance

(3) Seismic Load

Many earthquakes hit Bogota City including the one of magnitude 8 in 1917. There is a possibility to have big scale of earthquake in the future since some faults were found around the city. In this study, acceleration coefficient "A" in Bogota City is determined as A=0.2 following to the Codigo Colombiano de Diseno Sismico de Puentes. Further, horizontal force ratio against vertical force worked out from acceleration coefficient is determined as Cs=0.17.

(4) Materials

Strength of major materials is as shown in Table 15.5-1. Concrete strength is decided from current situation in the city and strength of steel follows ASTM.

Table 15.5-1 Strength of Materials

Materials	Note	Strength
Concrete	For Superstructure	fc=280kgf/cm2
	For Substructure	fc=210kgf/cm2
	For Prestress	fc=350kgf/cm2
Reinforcing bar	(Grade 40)	fv=2,800kgf/cm2
Prestressing Steel	(Grade270)	fv=161kgf/cm2
Structure Steel	(M-183)	fu=4,000kgf/cn2

Note fc: Specified compressive strength of concrete at 28 days

fv: Specified yield strength of reinforcement

fu: Minimum tension strength

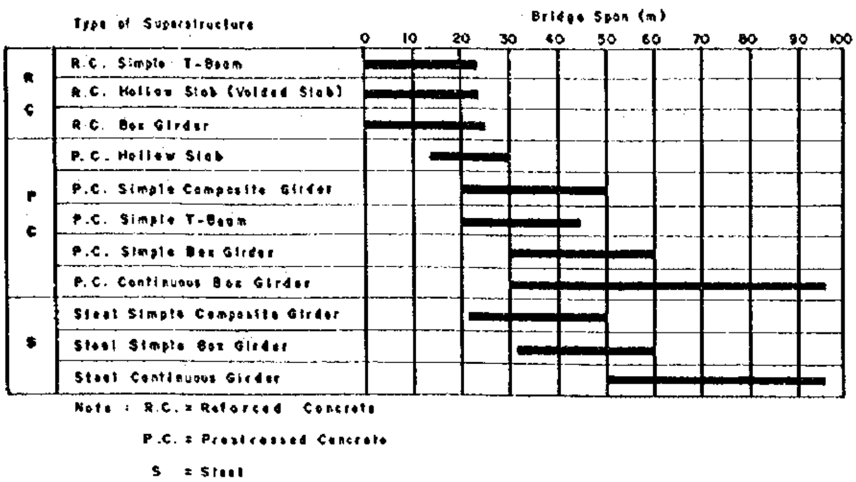
15.5.3. SUPERSTRUCTURE DESIGN

(1) General Conditions

In general, superstructure of bridge is classified as reinforced concrete, PC or steel. The economical standard span application of each type is as shown in Table 15.5-2. As described in Chapter 15.5.1 (1) all bridges built recently in the city are concrete bridges. Even in this study, superstructure is designed as concrete bridge basically taking availability of materials, economy and maintenance into consideration.

Concrete bridge is classified as RC (Reinforced Concrete) and PC (Pre-Stressed Concrete). RC is applied for short spans and PC is applied for medium to long span. Economical spans depend on ground conditions. If ground condition is good and hard, it is economical to use RC for superstructure and construct short spans since substructure and foundation costs would be low. If ground condition is poor and soft, it is economical to apply PC for superstructure and make medium spans since foundation costs would be high. In general, for over 30m span, superstructure cost increases drastically, therefore, it is said that spans of 25~30m are most economical. From perspective point, it is generally considered that bridge type of less beam depth and less number of columns is the most attractive. Taking the above factors into account, Expressway viaduct is planned as PC of 30m standard spans.

Table 15.5-2 Bridge type and Standard Span Application



(2) Overall Plan

The viaduct for Inner Ring Expressway (IRE) planned in this study is 16.44km in length and has four ON-OFF ramps. Superstructure type is classified in the following eight types.

Type1: Combined two lane dual carriage ways with 30m standard span.

Type2: Separated two lane dual carriage ways with 30m standard span.

Type3: At intersection with 30m standard span.

Type4: At intersection with 50m span

Type5: Similar to Type1 but with 40m span.

Type6: Similar to Type2 but with 40m span

Type7: Similar to Type1 but with 30~50m span.

Type8: Similar to Type2 but with 50m span.

Type1 and Type2 are described in this paragraph, Type3 and Type4 are described in paragraph (3) and Type5 to Type8 are described in paragraph (4) respectively. 30m standard span bridge is classified among the following four types judging from Table 15.5-2.

1) Hollow Slab
2) Simple Composite Girder
3) Simple T-Beam
4) Box Girder

From economic point of view, Box Girder is relatively expensive, however, other types do not show much difference in cost. Due to long continuous structure, consideration from perspective point (appearance) becomes important. From perspective point, Hollow Slab is the most attractive since beam is cast in-situ, shape can be selected and depth can be lower. On the other hand, beam depth of Simple Composite Girder and Simple T-Beam is higher and looks ugly, thus these types are considered to be less attractive. From construction point of view, Simple Composite Girder and Simple T-Beam have advantages since no support is required at the time of erection as required for pre-cast segmental beams. However, the viaduct is designed to have enough clearance to clear over pedestrian bridges, hence bridge type, such as Hollow Slab and Box Girder which require supports for casting concrete and erection, can also be coped with.

Taking the above facts into consideration, standard superstructure type for Expressway viaduct is decided as Hollow Slab which is superior in economy and perspective. Further, in case of Hollow Slab, it is more advantageous to have continuous beams than single span beams. Therefore, 3-span continuous span will be used for the standard section. Cross section of combined dual carriage way and separated dual carriage way are shown in Figure 15.5-4.

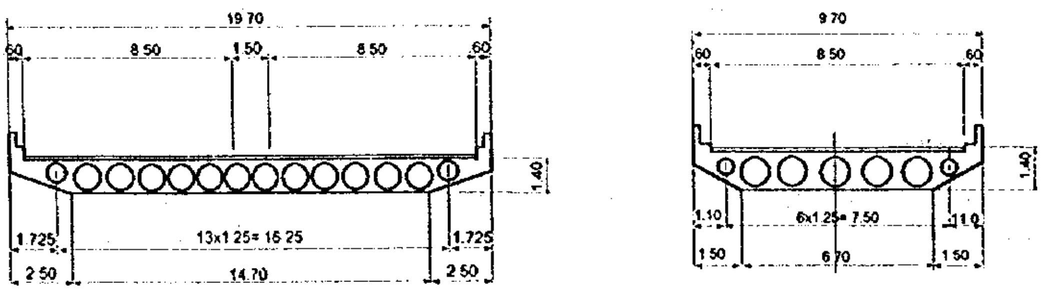


Figure 15.5-4 Typical Cross Section of Superstructure

(3) Intersection Section

Superstructure type at intersection is to be 3 continuous Hollow Slab spans. However, at ON-OFF ramp near Avenida Quito and Avenida Jimenez junction where columns cannot be constructed at 30m standard intervals, Steel Box Girder of 50m span is proposed since it is economical to have longer span with lighter weight of superstructure as much as possible. The typical cross sections of superstructure at the intersection are shown in Figure 15.5-5.

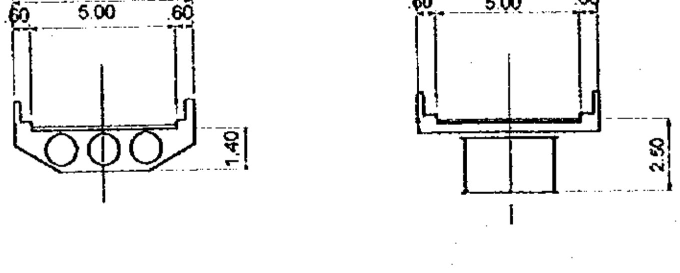


Figure 15.5-5 Typical Cross Section of Superstructure at Intersection

(4) Special Section

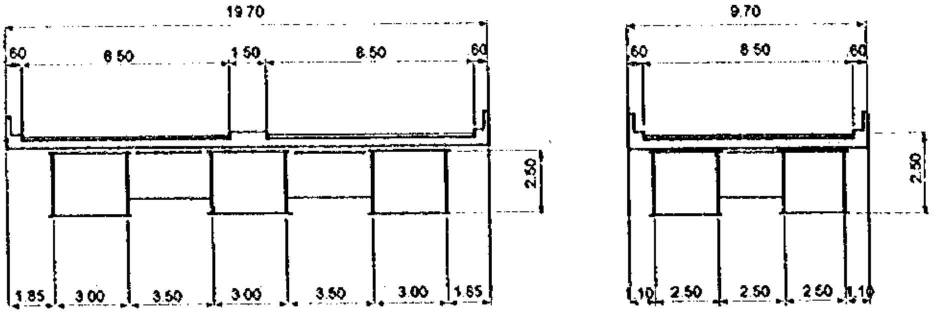
Special section is classified as the place where the viaduct crosses an existing flyover at the following two cases.

1) Calle is crossing Avenida Quito by flyover.
2) Avenida Quito is crossing Calle by flyover.

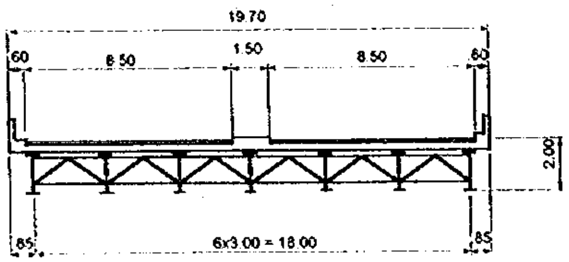
For item 1), 40m span viaduct is recommended, however, due to insufficient clearance to assemble support under beams, pre-cast segmental Simple Composite Girder which is commonly used in the city has to be considered for superstructure. Junction where Avenida Quito and Calle45 is crossing, 50m span Steel Box Girder is recommended since it is not feasible to provide columns at 40m intervals.

Item2) This occurs at junctions at Avenida Quito, Autopista El Dorado and Avenida De Las Americas and at Avenida Quito and Avenida Jimenez De Quesada. At the junction at Avenida Jimenez De Quesada, the weight of superstructure has to be light due to wider column of rigid frame, thus Steel Simple Composite Girder of 30m span is recommended. Junction at Autopista El Dorado and Avenida De Las Americas, the span has to be longer and the number of piers has to be minimized from economical point of view, thus Steel Box Girder of 50m span is recommended. Furthermore, at the junction at Calle 100, where roundabout with underpass is formed, the pier position is limited, thus Steel Box Girder of 50m span is also recommended.

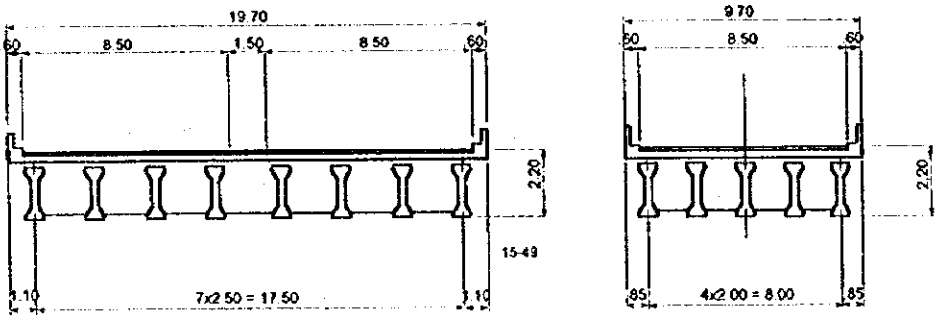
Cross section of special type superstructures are as shown in Figure 15.5-6.



STEEL BOX GIRDER



STEEL PLATE GIRDER



P.C. SIMPLE COMPOSITE GIRDER

Figure 15.5-6 Typical Cross Section of Superstructure on Special segment

15.5.4. SUBSTRUCTURE DESIGN

(1) General Conditions

It is usual to build substructures of RC concrete from economical point of view. Substructure of viaduct mainly consists of piers, and abutment is only used at an approach. Pier type and standard height application is as shown in Table 15.5-3.

Pier type and shape are decided by pier position determined from width of superstructure, road crossing arrangement and width of pier. As shown in Figure 15.5-7, planned carriageway height is 11m from road surface at standard section enable to clear pedestrian bridge. The high of the intersection is 14m from road surface sufficient to clear the existing flyover bridges. Taking the above factors into consideration, substructure types are classified into three groups, judging from Table 15.5-3.

1) Column Type
2) Rigid Frame Type
3) Wall Type

Selection of each type is made through careful study on the Expressway route alignment. For abutment, due to soft ground all through the route, ground settlement behind abutment by filling is highly envisaged thus abutment height is to be limited to 3m and 5.5m in full height. U shape retaining wall is provided behind abutment to support fills by abutment piles as a countermeasure for soft ground.

Table 15.5-3 Pier Type and Standard Height Application

TYPE		Height (m) (0 10 20 30 40)	Remarks
P-1	Column Type	0 – 15	
P-2	Rigid Frame Type (1 Storey)	5 – 15	
P-3	Rigid Frame Type (2 Storey)	15 – 25	
P-4	Wall Type	10 – 30	
P-5	Wall Type II Section	25 – 40	

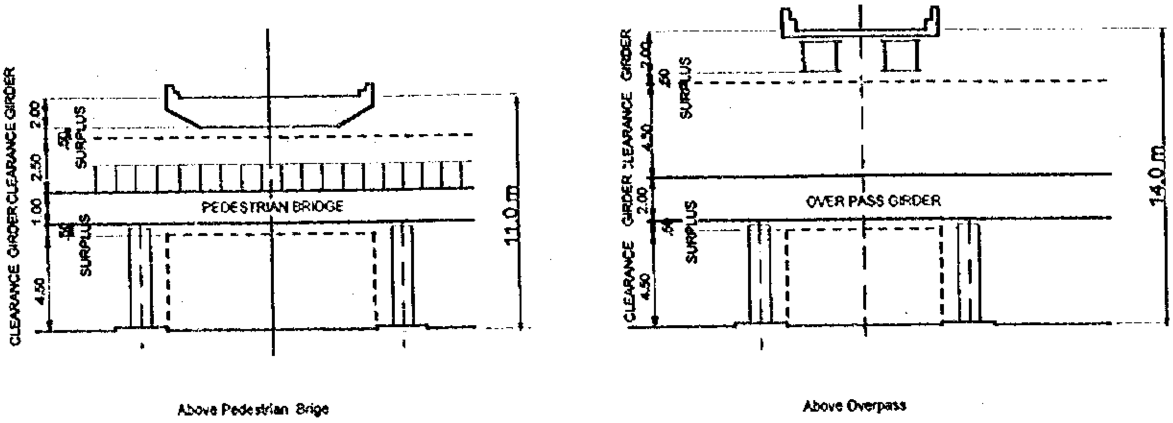


Figure 15.5-7 Vertical Clearance of Bridge

(2) Overall Plan

683 piers for both of main route and ramps for the Expressway viaduct are planned at this time. Substructure type is classified among the following seven types.

Type A: Wall Type pier to support combined two lane dual carriageway.

Type B: Rigid Frame Type pier to support combined two lane dual carriageway.

Type C: Column Type pier to support separated two lane dual carriageway.

Type D: Column Type pier to support ON-OFF ramp.

Type E: Wall Type pier to support ON-OFF ramp approach.

Type F: Abutment at approach.

Type G: Steel Rigid Frame Type pier for wider column leg spacing.

Type A~C are described below, Type D~F are described in paragraph (3) and Type G is described in paragraph (4) respectively. Type A is applied over Calle 100, since center separate trial width is 6m. Compare with superstructure width, bottom width is narrower, tapered shape pier is selected. Type B is proposed over Avenida7a, south side of Calle 68 over Avenida Quito and over Calle 6. Type C is proposed between Calle 100 and Calle 68 over Avenida Quito where piers are provided at outer separator. Cross section of each type is as shown in Figure 15.5-8.

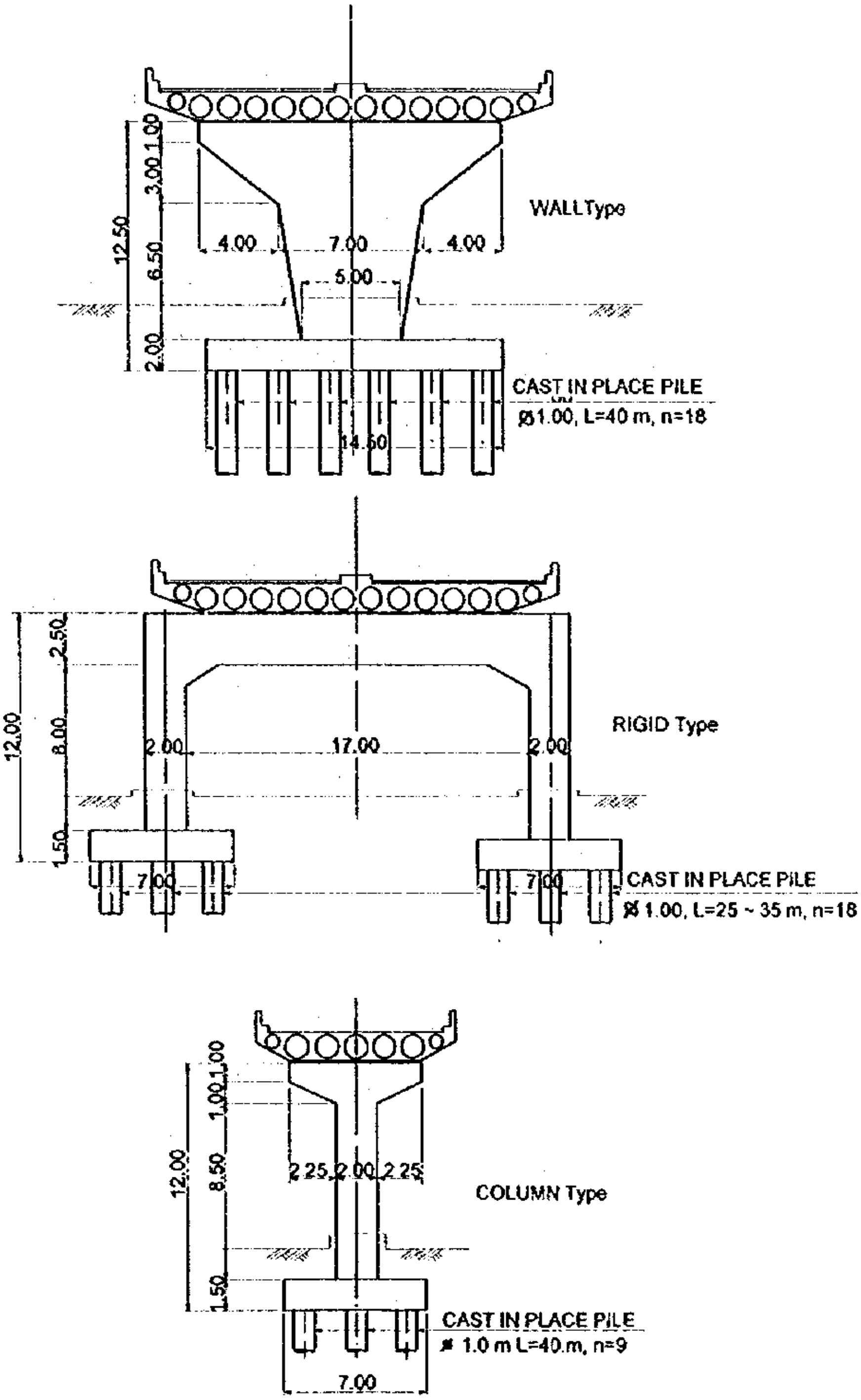


Figure 15.5-8 Typical Cross Section of Substructure

(3) Intersection

TypeD is propsed for ON-OFF ramp near Avenida 24 and Avenida Jimenez De Quesada since only ramp itself is to be supported. Type E is proposed for ON-OFF ramp at Avenida 7a which is North end of Expressway since future extension has to be considered. Cross section of each type is as shown in Figure 15.5-9.

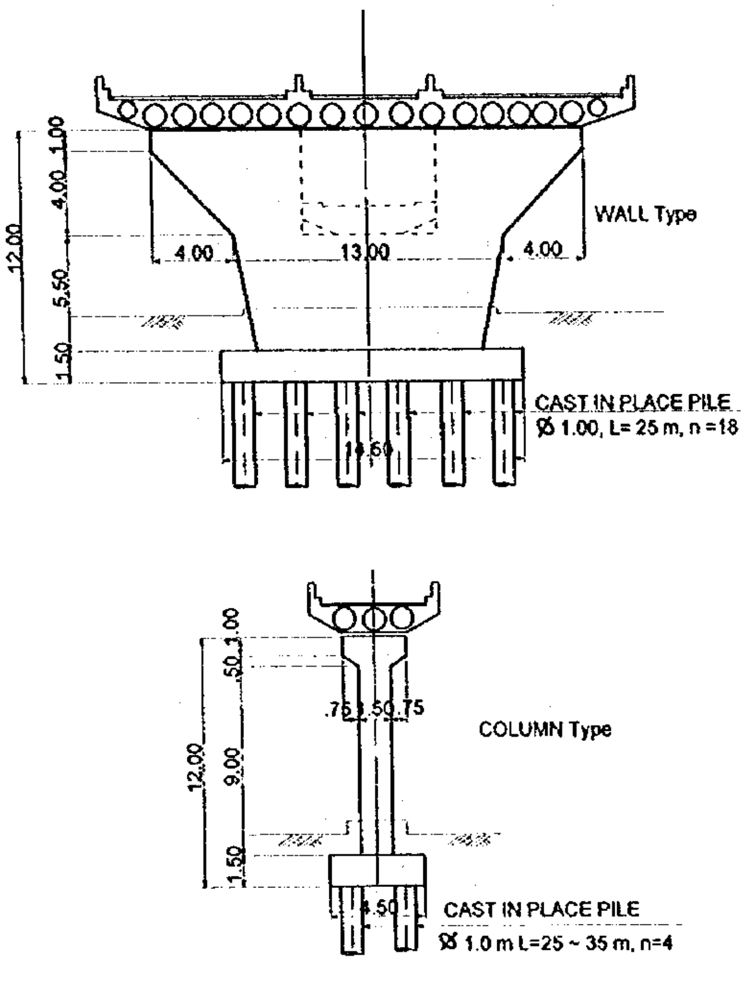


Figure 15.5-9 Typical Cross Section of Substructure at Intersection

(4) Special Section

TypeF is proposed for junction at Calle 45, between Autopista El Dorado and Avenida De Las Americas and Avenida Jimenez De Quesada over Avenida Quito since pier positions are limited and instead of RC, Steel Beams and Columns are required to support carriageway. Steel Pier has never been built in the city before, however, this type is commonly and successfully used for elevated urban expressways in Japan and U.S.A.. Cross section of pier is as shown in Figure 15.5-10.

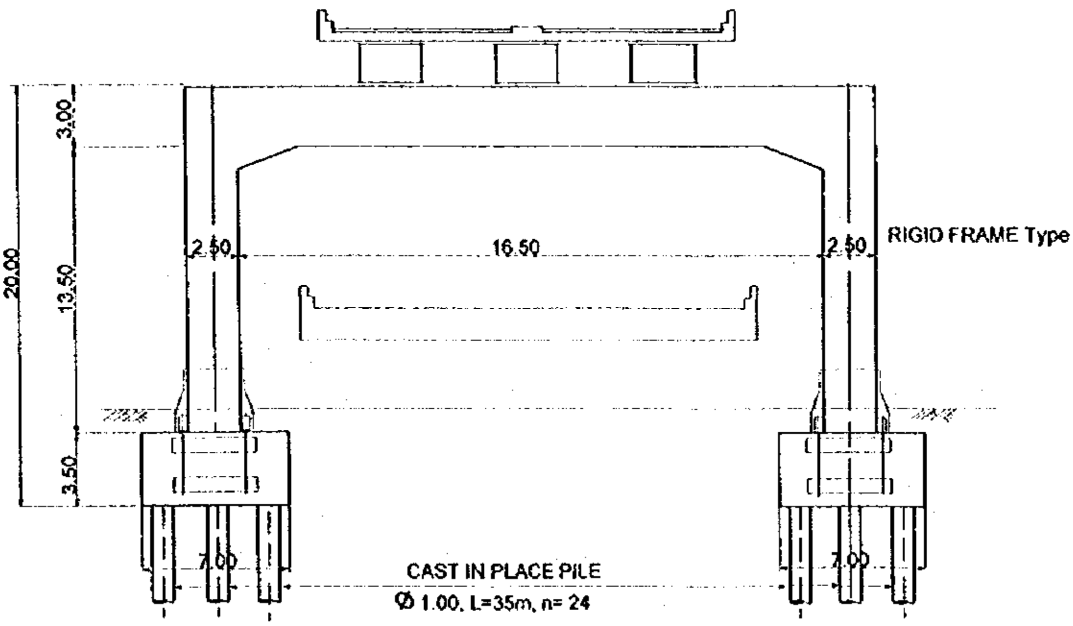


Figure 15.5-10 Typical Cross Section of Substructure

15.5.5. Foundation Design

(1) General Conditions

Ground condition of planned route is soft soil, which continues from surface to very deep. Therefore, pile foundation is used for all the structures. When driving piles, it is necessary to consider adopting methods to avoid or recuce noise, vibration etc., which affect city's environmental conditions. Cast in-situ bored RC pile and/or pre-cast auger pile are recommended.

Cast in-situ bored RC piles of ϕ0.6~0.8m are commonly used for bridge foundations in the city due to the availability of materials and equipment. Pile type and standard depth application is as shown in Table 15.5-4.

Table 15.5-4 Pile and Standard Depth Application

Type	Depth					Soil Condition		
	10	20	30	40	50	Clailey	Sandy	Boulder
Steel Pile	······	······	——	——	——	O	O	Δ
PC Pile		——	——			O	Δ	×
Cast in Place Pile			——	——	——	O	O	Δ

Note : O ; Applicable, Δ ; Possible, × ; No Applicable

(2) Pile Foundation

There are considerable experiences in Comumbia in the use of bored cast in-situ RC pile that has many experiences due to the availability of materials and equipment for use on foundations. In general, for large bridge structures, larger diameter piles have considerable advantages thus, ϕ1.0m of RC pile is recommended. Pile length and bearing capacity are discussed below.

1) 25m length of bearing pile is used for Avenida 7a section, since bearing strata exists at relatively shallow depth, and bearing capacity of pile is 300t under normal condition and 450t at seismic condition.

2) 40m length of friction pile is used for Calle 100 to Calle 68 on Avenida Quito, since no firm layer exists even beyond 40m depth. The bearing capacity of pile is 175t under normal conditions and 270t at seismic condition.

3) 35m length of bearing pile is used for Calle 68 on Avenida Quito to Calle 6, since a thin layer (1~3m thick) of sand with N value of approximately 30 exists at 35m depth. The bearing capacity of pile is 200t under normal conditions and 300t at seismic condition.

15.6. ISSUES FOR THE FURTHER DESIGN (FOR DETAILED DESIGN STAGE)

(1) To Clarify the Utilization of Existing Railway Area

The existing railway is passing through at the segment between Carrera 15 and Calle 68 on the existing Avenida Quito. The railway area is about 15 meters to 25 meters wide. At present, the future development plan of the railway such as how to use the railway area, re-location of railway, and how to improve railway system are not determined. When the detailed design will be commenced, these unknown factors should be defined, and a low cost design should be carried out.

(2) To Plant the Road Side Trees

The preliminary design of the Inner Ring Expressway is conducted considering the preservation of road side trees as much as possible, however, many road side trees on the existing Avenida 7a, Calle 100, Avenida Quito, and Calle 6 should be removed. The re-plantating of the existing trees, which are removed by the road construction, should be carried out as much as possible.

(3) To clarify the Underground Utilities

The preliminary design of Inner Ring Expressway was conducted including collection of data on underground utilities as well as to conduct the field reconnaissance survey, however, it is very difficult to find out detailed data on underground utilities. When the detailed design will be conducted, these data should be defined to prepare the construction method and to maintain the safety of construction.

The locations of existing major water pipe lines are as follows:

1) Autopista Norte (Toll gate to Call 129) .... 78 inches

2) Autopista Norte (Calle 129 to Calle 92)............ 60 inches

3) Avenida Boyaca (Calle 129 to end)................. 78 inches

4) Avenida Quito (Auto. Norte to Calle68) .... 60. 37 inches

The above mentioned pipe lines are located at 0.6 meters to 1.0 meters under the existing ground level. Minor water pipe lines such as 24 inches, and 17 inches are located at the major existing roads.

(4) To Get the Consensus of the Citizens

The people, who live in Bogota, may consider that the Urban Expressway will be constructed for vehicle owner only, because this road can be used only for vehicles. They may also be worried about the preservation of natural and social environmental aspects. Prior to the commencement of the detailed design for the Inner Ring Expressway, the necessity for the road, the economic and social benefits from the road, and effects of natural and social environment of the road should be explained to the citizens to gain the consensus of the citizens. For getting the consensus of the citizens, preparation for participating conference by the inhabitants may be needed as soon as possible.

15.7. OPERATION SYSTEM OF INNER RING EXPRESSWAY (IRE)

15.7.1. Maintaining of Good Service Level on IRE

The IRE is planned as urban expressway which has full access control with 4-lane dual carriageway and the 60 km/h to 80 km/h design speed. The IRE employs a toll road system. A tollgate is located on each ramp-way. The IRE should be kept a good service level, especially; comparative high speed should be served against the rate of a toll charge.

According to the experience of Japanese Urban Expressway, when the running speed on the Urban Expressway decreases by 20 km/h or less, the on-off rumps have been closed for keeping a good traffic service level on the Urban Expressway. Therefore, the IRE should introduce the above-mentioned manner to maintain a good traffic service level on the proposed IRE. In addition, since the running speed also decreases when traffic accidents will occur on the IRE, it also proposes the restriction of service for the on-off rumps.

For keeping a good traffic service level on the IRE, the provision of operation system, maintenance system, and traffic information systems on the IRE are also indispensable.

15.7.2. Toll Charge and Collection Method

The future traffic volume on the IRE depends on the rate of toll charge. When the toll charge is lower, the large traffic volume is forecasted. To the contrary, when the toll charge is higher, the traffic volume is light. The future traffic volume on the IRE was forecasted based on the three (3) toll charge alternatives: 2,000 pesos, 3,000 pesos, and 4,000 pesos. The toll rate is decided at 2,000 pesos in the year 2006 and 3,000 pesos in the year 2015, based on the sensitivity analysis between future traffic volume and revenue of toll charge.

The flat rate system is employed as the toll charge system of IRE, to be short in the road length of the IRE, and to avoid the confusion on the rump ways in case of a zone fare system in which the fare raises according to trip length.

15.7.3. Traffic Capacity on Tollgate

When vehicles pass the tollgate, drivers must done the following four (4) actions at the tollgate.

1) To decelerate a vehicle running speed

2) To pay a toll charge

3) To receive change and receipt

4) To accelerate the speed again

According to the data of Japanese Urban Expressway, three (3) seconds to four (4) seconds were needed to complete the total actions at the tollgate. Therefore, the ramp capacity in one direction at the tollgate can be calculated at about 900 vehicle per hour (v/h) to 1,200 v/h (36,000/3=12,000, 36,000/4= 900).

Based on the traffic assignment in the year 2015, the traffic volume on the rump way is forecasted at about 12,000 vehicle per day on both directions. This figure is equivalent to about 700 vehicle per hour in one direction. In comparing capacity to future traffic volume, the future traffic volume can be controlled at tollgate on the rump way.

In the future, when the traffic volume will exceed the tollgate capacity (900 to 1,200 v/h), two (2) toll collection booths at the one tollgate will be provided or two (2) tollgates on the rump way will be constructed due to increase the capacity at the tollgate.