REPUBLIC OF THE PHILIPPINES

THE FEASIBILITY STUDY FOR

MANILA RAPID TRANSIT RAILWAY LINE NO. I

APPENDIX COMPARATIVE STUDIES BETWEEN MONO-RAIL AND TWO-RAIL TYPE RAILWAY SYSTEM

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CHAPTER 1

GENERAL

For the planning of the Rapid Transit Railway RTR Line No. 1 in the Manila Metropolitan Area (M.M.A.), it is necessary to select an urban mass transportation system with an adequate function and a satisfactory service pattern to meet the traffic demand in the area.

The selection of an optimum type of mass transportation system involves an extensive study of a variety of factors, such as the future development of suburban areas along the proposed route, environmental problems and complex technicalities of the transit system, not to mention the financial viability of the investment for the construction.

Every city has its own characteristics and a peculiar function to perform. In each city there exists one type of mass transportation system or other which meets the peculiar characteristics of the city. This means that any mass transit railway to be built in a city with a peculiar function, a peculiar traffic demand pattern and existing mass transportation means must be planned from a comprehensive point of view so that it may serve as the most desirable transit system to realize the effective distribution of all passenger traffic of the whole metropolitan area.

Japan International Cooperation Agency (formerly called Overseas Technical Cooperation Agency) proposed a master plan for the construction of a rapid transit railway system in the M.M.A in its Urban Transport Study of the Metro Manila Area (UTSMMA, 1973) on the basis of its estimate of traffic demand in 1978 and 2000. JICA concluded in its UTSMMA that five lines of rapid transit railway would be necessary to meet the future traffic demand in the M.M.A.

This feasibility study has been concentrated on the accumulation of information required to plan Rapid Transit Railway Line No.1 which is considered to take precedence of the other four, as has been indicated by the consideration of the pattern of traffic demand growth in the M.M.A. in the course of this feasibility study.

For one reason or another, the UTSMMA does not evaluate in detail various new traffic systems including the exclusive bus lanes which has been proposed in various parts of the world to offer a solution to the urban traffic problems. In the M.M.A. however, development is so advanced that it seems practically difficult to adopt such new traffic systems in the light of the future traffic demand in the metropolitan area studied in this report. The enormous traffic demand in the M.M.A. could not possibly be met by any transit system other than the railway system or the heavy rail transit (HRT) system which is proposed in this feasibility study. If the traffic demand is to be met by a wholly elevated HRT system, it will disfigure the landscapes of some of the scenic places along the route, which are hardly seen in other cities, and it will also be incompatible with the city function required in the highly built-up areas like Santa Cruz, Binondo and part of Taft Avenue with narrow streets. Furthermore, since elevated stations extend more than 20 m in width and 120 m in length, the elevated HRT system is not recommendable. In spite of these disadvantages of the elevated system, it has been considered in this feasibility study in great detail because it is cheaper to construct than the subway system. In the consideration of the elevated system, the mono-rail system and the two rail system have been compared from a general point of view, and as a result of this comparison only the two rail system is subjected to detailed feasibility study.

In recent years, various new traffic systems including the exclusive bus lanes have been studied in many parts of the world. To keep abreast of the new traffic system research in the world, mention will be made of such new traffic systems in Part II of the Interim Report. As for the mono rail system and the two rail system.

CHAPTER 2

OUTLINE OF URBAN TRANSIT SYSTEM

The urban transit system to be introduced into the Metro Manila Area calls for a careful prior study of various factors from a broad viewpoint. Specifically, it is necessary to confirm that the system will meet both the prospective traffic demand and users' needs, present no particular technical difficulties to the management authority, produce no pollution problems, promote regional development, and make efficient three-dimensional space utilization possible. In addition, the new system is required to function in perfect harmony with the probable future development of the region. Hence, the system should be such that it is considered most desirable for and compatible with the present as well as future urban functions and characteristics.

In this chapter a number of urban traffic systems that may be introduced in the M.M.A. are presented and each one of them is briefly evaluated.

2.1 Classification of New Urban Transit Systems

Physical characteristics of the urban transit system are classified as follows.

(a) Vehicle capacity
- (i) Heavy
- (ii) Medium
- (iii) Light

(b) Personal/omnibus service
- (i) Personal
- (ii) Omnibus

(c) Seat arrangement	(i) Seat only
	(ii) Seat with space for standing passengers
	(iii) Standing space only
(d) Type of system	(i) Guideway transit system
	(ii) Non guideway transit system
(e) Service activation	(i) Personal activated
	(ii) On-demand activated
	(iii) Fixed schedule
(f) Type of guideway	(i) Non guideway (Roadway)
	(ii) Two rail
	(iii) Mono-rail
	(iv) Cable
	(v) Guideway
(g) Operation	(i) Automatic control
	(ii) Operator control
	(iii) Passenger control
(h) Vehicle type	(i) Small cabin
	(ii) Heavy vehicle
(i) Route alignment	(i) Line haul
	(ii) Network (Areal and/or Loop)
	(iii) Variable

The following are the transit system classified on the basis of these physical characteristics.

Table 2.1 Characteristics of Urban Transport Systems

		Vehicle Capacity			Type of Service		Seat Arrange-ment			Type of System		Service Activa-tion			Type of Guideway				Operation			Vehicle Type			Route Alignment		
		Heavy	Medium	Light	Personal	Omnibus	Seat	Seat/Standing	Standing	Guideway	No-Guideway	Personal	On-Demand	Fixed-Schedule	No-Guideway	Dual Rail	Monorail	Cable	Automatic	Operator	Passenger	Small Cabin	Medium Vehicle	Heavy Vehicle	Line Haul	Network	Variable
Light Guideway Transit			0			0	0	0		0			0					0	0		0		0			0	
Personal Rapid Transit				0	0	0	0			0		0	0					0	0			0				0	
Heavy Rapid Transit	Monorail	0				0		0		0				0			0			0				0	0		
	2 Rail	0				0		0		0				0		0				0				0	0		
Light Rail Transit				0		0		0		0				0		0				0			0		0		
Bus Transit		0		0		0		0			0		0	0	0					0			0				0

1. Light guideway transit system
2. Personal rapid transit system
3. Heavy rail transit system
    (a) Mono-rail system
    (b) Two-rail system
4. Light rail transit system
5. Roadway transit system

The physical characteristics of these systems are summarized in Table 2-1 and described as follows:

1. Light guideway Transit (LGT)

    Vehicles are operated singly and in some cases in small trains over an exclusive guideway under automatic control. Stations can be either on-line or off-line. The vehicles are usually the size of a small bus with approximately the same passenger capacity permitting standing. In the off peak hours some systems may offer personal, demand activated service. (Fig. 2.1)

2. Personal Rapid Transit (PRT)

    PRT is a transit class in which small vehicles (2 to 6 passengers seated) operate under total automatic control over an exclusive guideway. All stations are off-line and service is demand activated. By "personal" it is meant that one passenger can have exclusive use of a vehicle for a non-stop trip from his origin station to

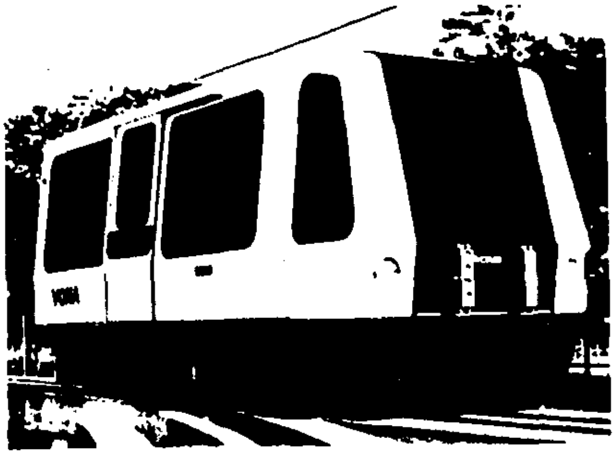


Fig. 2.1 Light Guideway System

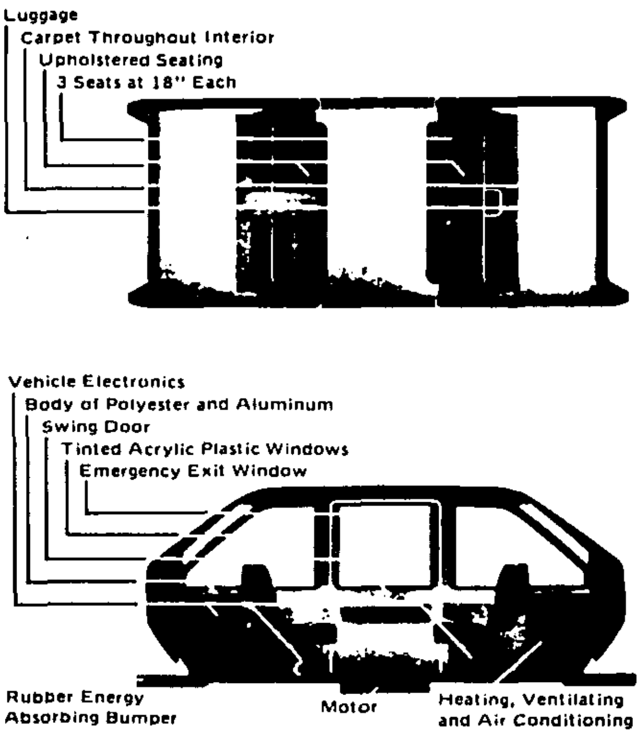


Fig. 2.2 Personal Rapid Transit

his destination station. He may take with him a small party of perhaps three to five others, possibly at no extra charge.

In the literature a number of names are used for PRT: Advanced PRT, High-Capacity PRT, Taxi-Transit, and Capsule Transit.

Also included in the PRT class is the concept of dual-mode. In this case the vehicle may be a type that can leave the PRT guideway and be operated on the surface streets as an automobile. (Fig. 2.2)

3. Heavy Rail Transit (HRT)

Systems in this category are usually characterized as 8 to 10 feet wide trains of 25 to 35 ton vehicles with on-line stations. This would include subways and commuter trains. Also included are the large variety of mono-rails that offer essentially the same class of service as subways. Some examples of systems in this class are BART, Toronto GO TRAIN, Montreal rubber-tyred METRO, and the new Washington D.C. METRO.

This classification has been subdivided futher as follows.

A. Mono-rail System

B. Two-Rail System

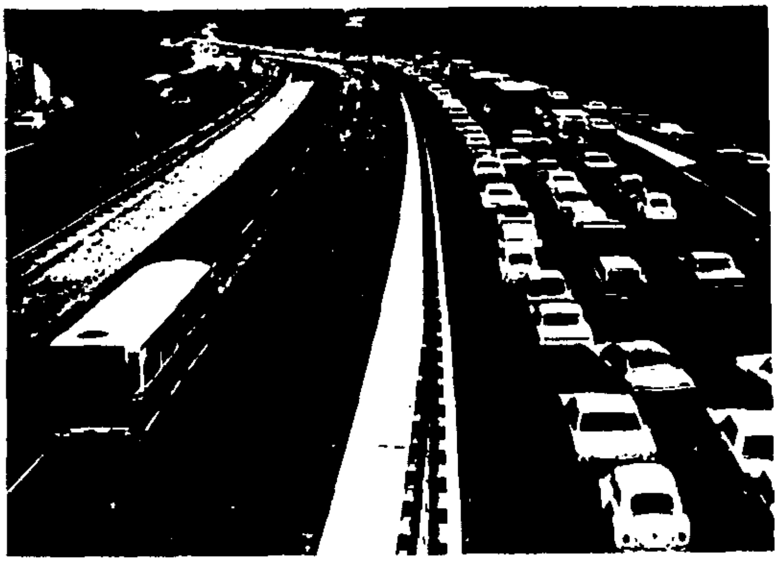


Fig. 2.3 Bus Transit System

4. Light Rail Transit (LRT)

The "Streetcar" or "Tram" is typical of this class of LRT which usually, has vehicles operating singly or in pairs, with or without an exclusive right-of-way. The gross weight of an LRT vehicle usually ranges from 15 to 18 tons.

5. Roadway Transit Systems

Roadway Transit Systems are characterized by vehicles supported by rubber tyres and operating on surface roads and streets. The vehicles in this class are of the automobile and bus types. In most cases the vehicles are mixed with other traffic, but may also have use of an exclusive busway lane. It also includes priority measures given to buses at entrances to freeways and at traffic signals and dual-mode bus systems. (Fig. 2.3)

2.2 Brief Study of Each Urban Transit System

Each of the alternative transit systems classified above and considered for introduction into the Metro Manila Area was briefly studied below.

(1) Light Guideway Transit (LGT)

The Light Guideway Transit has a passenger capacity standing midway between the Roadway Bus Transit System and the Monorail System, and it is primarily intended to meet the demand for short-distance transportation with high-frequency service. Hence, it is not suited to the purpose of line haul transit reviewed in the this study.

In addition, this system is still in the course of development and consequently rejects any definite prediction as to its future progress. Detailed study of this system should therefore be made at some later date.

(2) Personal Rapid Transit (PRT)

The Personal Rapid Transit has a smaller passenger capacity than LGT because small vehicles are used. Hence, it should be excluded from the scope of the this study because of its low capacity.

(3) Light Rail Transit (LRT)

Streetcars and mini-monorail trains are typical of the class of LRT which, however, are not commendable on account of its small passenger capacity.

(4) Heavy Rail Transit (HRT)

The Heavy Rail Transit is subdivided into the Monorail System and the Two (Dual) Rail system which both provide a very large transport capacity. A detailed study of the two systems is therefore made in chapter 3.

(5) Bus Transit (BT)

The following two cases can be divided for the Bus Transit Operation.

a) Buses mixed with other vehicles on the roadways.

b) buses operating on the exclusive bus lanes and/or the exclusive busway.

The case B can be further subdivided according to the following definition.
EXCLUSIVE BUS LANES are treatments applied generally to city streets where one or two lanes of the street are reserved for buses only. In some cases taxis, carpools, and emergency vehicles are permitted. These lanes may be reserved throughout the day or specific hours.
The technique is generally a low cost technique which has been accomplished through passing of city ordinances, proper enforcement, and application of painted markings, signs, and traffic barriers.

CONTRA-FLOW BUS LANES have also proven to be another cost effective approach. In many cities a typical divided street or highway usually has one of its directions saturated with traffic in the morning or evening peak period. A contra-flow lane is one which is temporarily placed on the low density side where the flow of buses opposes the normal flow of traffic. It is necessary to erect temporary traffic barriers, signs, active traffic signalling, and some forms of enforcement for the hours of operation to insure that the opposing normal traffic does not enter the lane.

EXCLUSIVE BUSWAYS are specially built roads for exclusive use by buses. They may have limited access for buses to enter and exit or none at all whereby the buses remain on the busway at all times. Some treatments use the median or side of a freeway for the permanent construction of the busway. In other cases specially designed elevated structures have been applied.

EXPRESS BUS service, while it is not a technology, usually is combined with one or more engineering improvements (e.g. exclusive busways, exclusive lanes, priority at freeway entrances, etc.)

The maximum traffic flow of the above mentioned systems is shown in Table 2.2 and that in the exclusive bus lanes and the contra-flow bus lanes is approximatly 2,500 to 4,000 passengers/peak hour and that of the exclusive busways is almost 4,000 to 6,000 passengers/peak hour. Hence, it is not suited to the purpose of the trunk mass transit system.

Table 2.2 Max. Bus Flow by Bus Transit Improvements

Location	Route Length (Kms)	Hours of Operation	Max. Flow Buses (vehicles)	Passengers	Remarks
Paris, Fance	52.4	24 hrs	108/hr	-	134 exclusive bus lane & 9 Contra-flow lanes
Ottawa, Canada	16.1	Peak periods	-	4,500/day	Exclusive bus lanes
London, England Park Lane	0.2	4 - 7 pm	140/hr	-	"
Marseilles, France	9.5	7am-8pm	120/hr	14,500/day	Exclusive Bus Lanes
Toronto, Canada	1.93 3.22	7 - 9 am 4 - 6 pm	70/hr 80/hr	5,000/2h 9,500/2h	Morning Bus Priority Evening Lanes
Boston, USA Southeast Expressway Exclusive Bus Lane	13.5	6.30-9.30 am	90/3h	2,454/3h	Contra-Flow Bus Lane
1-1419 New Jarsey. USA	4.0	7 - 10 am	500/hr	25,000/hr	From the New Jersey Turnpike to the Lincoln Tunnel, No Busstop Contra-Flow Bus Lane
Indianapolis USA	4.58	-	95/day	-	Contra-Flow Bus Lane
San Francisco USA	6.4	4 -6.30pm	70 to 90/hr		Contra-Flow Bus Lane
Chicago, USA Proposed Crosstown Busway	32	24 hrs	120/hr	6,000/hr	Exclusive Busway
Dallas, USA Proposed North Central Busway	16.1	24 hrs	80/hr	19,300/day 4,000/hr	Exclusive Busway
Los Angeles, USA San Bernardino Busway	17.7	24 hrs.	100/hr	17,000/day 4,000/hr	Exclusive Busway

CHAPTER 3

COMPARISON OF THE TWO-RAIL AND MONO-RAIL SYSTEM

3-1. Basic Assumptions for Comparison of Mono-rail and Two-rail

The comparison of the mono-rail and two-rail systems in their complex technical aspect will be too large a subject to cover briefly, if they are to be compared from the stage of network planning in connection with traffic demand in Manila city. In consideration of the nature of this study, therefore, the comparison of the two railway systems will be based on the following assumptions.

3-1-1 Route

The mono-rail shall be compared with the two-rail, assuming that the route is the same as Line No.1 of the Rapid Transit Railway considered in the master plan of the integral urban traffic network of Manila city prepared in 1973.

3-1-2 Two-rail and Mono-rail System

This study makes it an aim to compare the two-rail system with the mono-rail system. The mono-rail is built with two types of track structure, saddle mono-rail and suspension mono-rail, but their comparison is beyond the scope of this study.

3-1-3 Construction Planning

(1) The mono-rail is generally conceived as a line which is elevated from end to end. If it is possible to build an elevated mono-rail system in Manila city, it is also possible to build the two-rail at an elevation. Any comparative study should be conducted on the same basis. If one traffic system goes underground and the other is elevated, it is self-evident that the elevated

system is far cheaper to construct. In this study, therefore, the mono-rail and two-rail systems will be compared on the same basis as to such considerations as structural problems, construction costs, environmental problems and safety. In this respect, it is worth noting that where a section is proposed underground for the two-rail system, the conditions of the environment necessitate that the mono-rail system will also have to be constructed underground.

(2) A mass transit railway system which is to be constructed in built-up areas of a big city should go underground for various reasons. On the other hand, however, the transit system must be elevated to construct it at lower cost. For this reason the mono-rail and the two-rail system have been compared in this study on the assumption that the system, whichever it is, will be elevated above the surface where possible.

3-1-4 Rolling Stock

The comparison of rolling stock between the mono-rail and two-rail systems is not concerned with the rolling stock which may be newly developed and designed for Manila Rapid Transit Railway. The rolling stock currently in use in existing mono-rail and two-rail lines will be considered in this study.

3-2 Mono-rail and Two-rail Systems Currently in Operation

The comparison of mono-rail and two-rail systems currently in operation in various parts of the world will furnish valuable information which will be of great help to the Department of Public Works, Transportation and Communications of the Government of the Philippines in planning a mass transit system.

The mono-rail and two-rail systems in operation in various parts of the world are summarized in Tables 3.1 and 3.2.

As is well-known, the two-rail system has been adopted by the vast majority of world big cities, but only a few operate the mono-rail system and its total route length is very short, as shown in Table 3.2.

Although the mono-rail has a history of 70 years as a mass transit system, it has thus far not been considered suited for mass transportation in urban districts. Japan leads other countries in mono-rail construction. When the Haneda Mono-rail Line was opened in 1964, cars of high traffic capacity were developed and its high practical value has been proven over years of operation. This mono-rail system has contributed a great deal to the solution of urban traffic problems, as a supplemental means of urban transport to the extensive subway and other two-rail transit network in Tokyo.

Table 1. – . Two-rail System Adopted in Various Cities in the World

Year of Inaugu-ration	Number of Metropolitan	Name of Corporation	Operating kilometer		Number of Lines	Number of Station	Annual Traffic Volume	Train For-mation	Head-way	Number of Cars
			Under-ground	Total						
S.L 1863 E.L 1890	London (ENGLAND)	London Transport Executive	165.6	387.6	8	249	655,000	8	2:00	4,315
1896	Budapest (HUNGARY)	Budapest Railway	11.8	12.8	2	22	21,900	4	2:00	133
1897	Glasgow (ENGLAND)	Glasgow Transport Bureau	10.5	10.5	1	15	15,300	1	3:30	43
1898	Wien (AUSTRIA)	Wien Transit Authority	18.2	26.7	1	25	72,500	0	2:30	330
1900	Paris (FRANCE)	Autonomy Corporation of Paris Transports	178.4	248.1	19	393	1,224,000	9	1:35	3,656
1901	Boston (U.S.A.)	Massachusetts Bay Trans-portation Authority	15	48	3	48	95,000	4	2:00	356
1902	Berlin (GERMANY)	Berlin Transit Authority	81.2 W 68.8 E 12.4	103.5 88.9 14.6	10 8 2	131 109 22	331.600 270,600 61,000	8	2:30 2:00	1,164 858 306
1904	New York (U.S.A.)	New York City Transit Authority	220	385	37	477	1,227,800	11	1:30	6,924
1907	Philadelphia (U.S.A.)	Southeastern Pennsy-lvania Transportation Authority	26.2	39.4	2	53	1,100,000	6	1:45	490

Year of Inauguration	Number of Metropolitan	Name of Corporation	Operating Kilometer		Number of Lines	Number of Station	Annual Traffic Volume	Train Formation	Headway	Number of Cars
			Underground	Total						
1908	New York (U.S.A.)	Port of New York Authority-Trans Hudson	12.8	22.4	1	13	40,300	7	1:30	298
1912	Hamburg (GERMANY)	Hamburg Verkehrsverbund	32	90.7	3	79	187,200	8	2:00	849
1913	Buenos Aires (ARGENTINE)	Buenos Aires Transit Authority	34	34	5	57	261,100	5	2:00	402
1919	Madrid (SPAIN)	Madrid Underground Railway Corporation	50.9	50.9	6	84	502,000	6	2:30	608
1924	Bercelona (SPAIN)	Barcelona Underground Railway	33.0	34.0	4	52	241,100	4	2:40	296
1925	Athens (GREECE)	Greece Electric Railway	2.9	25.7	1	20	92,300	5	3:30	135
1927	Tokyo (JAPAN)	Teito Rapid Transit Authority	Ginza L 14.0 Marunouchi L 25.2 Hibiya L 17.4 Toozai L 16.5 Chiyoda L 18.7 Total 91.8	14.3 27.4 20.3 30.8 20.9 113.7	5	18 27 21 20 18 104	1,353,548	10	2:00	1,402

Year of Inauguration	Number of Metropolitan	Name of Corporation	Operating Kilometer		Number of Lines	Number of Station	Annual Traffic Volume	Train Formation	Headway	Number of Cars
			Underground	Total						
1929	Barcelona (SPAIN)	Salia Railway	4.4	7.1	1	12	26,500		2:30	72
1923	Osaka (JAPAN)	Osaka Municipal Transportation Bureau	Midousuji L 14.1	19.5	6	17	722,883	8	2:15	625
			Tanimachi L 7.3	7.3		8				
			Yotsubashi L 11.4	11.4		11				
			Chuo L 6.4	12.3		11				
			Sennichimae L 9.6	9.6		11				
			Sakaesuji L 7.0	7.0		9				
			Total 55.8	67.1		67				
1935	Moscow (U.S.S.R.)	Moscow Underground Railway	132.4	150.4	8	96	1,628,000	7	1:30	1,800
1943	Chicago (U.S.A.)	Chicago Transit Railway	17	143	4	154	103,500	8	1:55	1,295
1943	Stockholm (SWEDEN)	Stockholms Sparvagar	26.5	70.5	2	72	187,000	8	2:00	696
1954	Toronto (CANADA)	Toronto Transit Commission	32.0	42.0	2	47	169,000	8	2:20	410

Year of Inaugu-ration	Number of Metropolitan	Name of Corporation	Operating kilometer		Number of Lines	Number of Station	Annual Traffic Volume	Train For-mation	Head-way	Number of Cars
			Under-ground	Total						
1955	Rome (ITALY)	Rome Electric Railway	5.9	11.0	1	11	21,800	3	6:00	40
1955	Cleveland (U.S.A.)	Cleveland Railway	0.5	30.5	1	17	13,290	6	2:00	118
1955	Leningrad (U.S.S.R.)	Leningrad Underground Railway	44.4	45.0	3	29	399,300	4	2:00	247
1957	Nagoya (JAPAN)	Nagoya Municipal Transportation Bureau	Higashiyama L 15.0 Meijo L 14.9 Total 29.9	17.5 14.9 32.4	2	19 17 36	208,942	5	2:00	262
1959	Lisbon (PORTUGAL)	Lisbon Underground Railway Corporation	12.0	12.0	1	20	70,400	2	2:00	70
1960	Tokyo (JAPAN)	Tokyo Metropolitan Transportation Bureau	No. 1 18.3 No. 6 17.4 Total 35.7	18.3 21.0 39.3	2	42	238,719	6	2:30	308
1960	Kiev (U.S.S.R.)	Kiev Underground Railway	35.7 13.0	39.3 20.3	1	15	126,800	3	2:00	146
1964	Milan (ITALY)	Milan Municipal Transportation Bureau	20.7	34.2	2	43	125,600	6	3:00	219

Year of Inaugu-ration	Number of Metropolitan	Name of Corporation	Operating kilometer		Number of Lines	Number of Station	Annual Traffic Volume	Tain For-mation	Head-way	Number of Cars
			Under-ground	Total						
1966	Oslo (NORWAY)	Oslo Underground Railway	7.4	28.2	1	35	28,000	6	3:30	135
1966	Montreal (CANADA)	Montreal Transportation Commission	25.6	25.6	3	28	127,400	9	2:00	369
1968	Kobe (JAPAN)	Kobe Rapid Transit Railway Corporation	Toosei L 6.9 Nanbolu L 0.4 Total 7.3	7.2 0.4 7.6	2	9 1 10	85,085	7	2:00	0
1968	Rotterdam (NETHERLAND)	Rotterdam Electric Railway	3.2	7.6	1	8	28,000	4	3:00	43
1969	Philadelphia (U.S.A.)	Philadelphia Trans-portation Bureau	4.6	23.3	1	12	9,500	6	5:00	75
1971	Sapporo (JAPAN)	Sapporo Municipal Transportation Bureau	7.6	12.1	1	14	71,565	6	5:00	72
1972	Yokohama (JAPAN)	Yokohama Municipal Transportation Bureau	5.3	5.3	1	6	21,796	3	5:00	21

Table 3.2 Mono-rail System in the World

Year of Inaugu-ration	Name of Country	Location	Type	Purpose	Track Length	Remarks
1901	West Germany	Wupportal	Suspension Type	Passenger Transport	13.3 km	Double Track
1956	West Germany	Freilingen	Saddle Type	Experimentation	1.8	Single Track
1957	Japan	Tokyo Ueno	Suspension Type	Amusement	0.33	do
1959	U.S.A.	Disneyland	Saddle Type	do	1.34	do
1960	France	Orleans	Suspension Type	Experimentation	1.4	do
1961	Italy	Torino	Saddle Type	Passenger Transport	1.16	do
1961	U.S.A.	Disneyland	do	do	2.6	do
1961	Japan	Nara	do	Amusement	0.9	do
1962	Japan	Inuyama	do	Passenger Transport	1.29	do
1962	U.S.A.	Seattle	do	do	1.59	Double Track
1963	Japan	Yomiuri land	do	do	1.97	Single Track
1964	Japan	do	do	do	1.13	do
1964	Japan	Haneda	do	do	13.1	Double Track
1966	Japan	Mukogaoka	do	do	6.6	Single Track

3-3 Rolling Stock

As will be discussed later, the traffic capacity of the track itself little differs from the two-rail to the mono-rail, although the train length is slightly different from one to the other.

Mention will now be made of the differences in rolling stock between the two railway systems with reference to major problems.

The rolling stock dimensions of the car used in two-rail track, the car used in saddle type mono-rail track and the car used in suspension mono-rail track are shown in Fig. 3.1.

3-3-1 Passenger Capacity

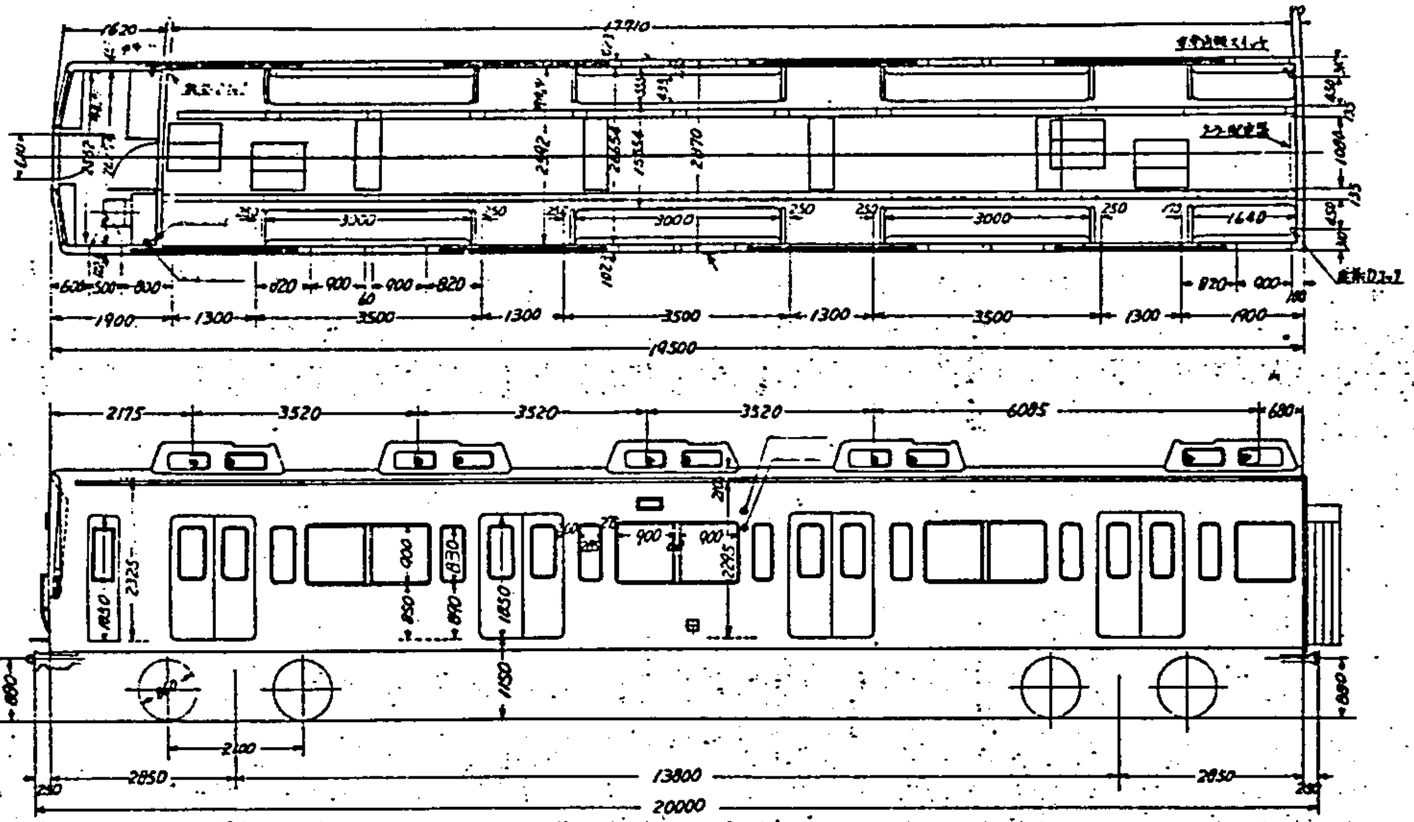
The maximum passenger transport capacity of one car in the three systems during one peak hour period is summarized as follows.

System	Capacity	Car Length
Two-rail	204 persons/car	20 m
Saddle mono-rail	151 persons/car	15.65 m
Suspension mono-rail	151 persons/car	17 m

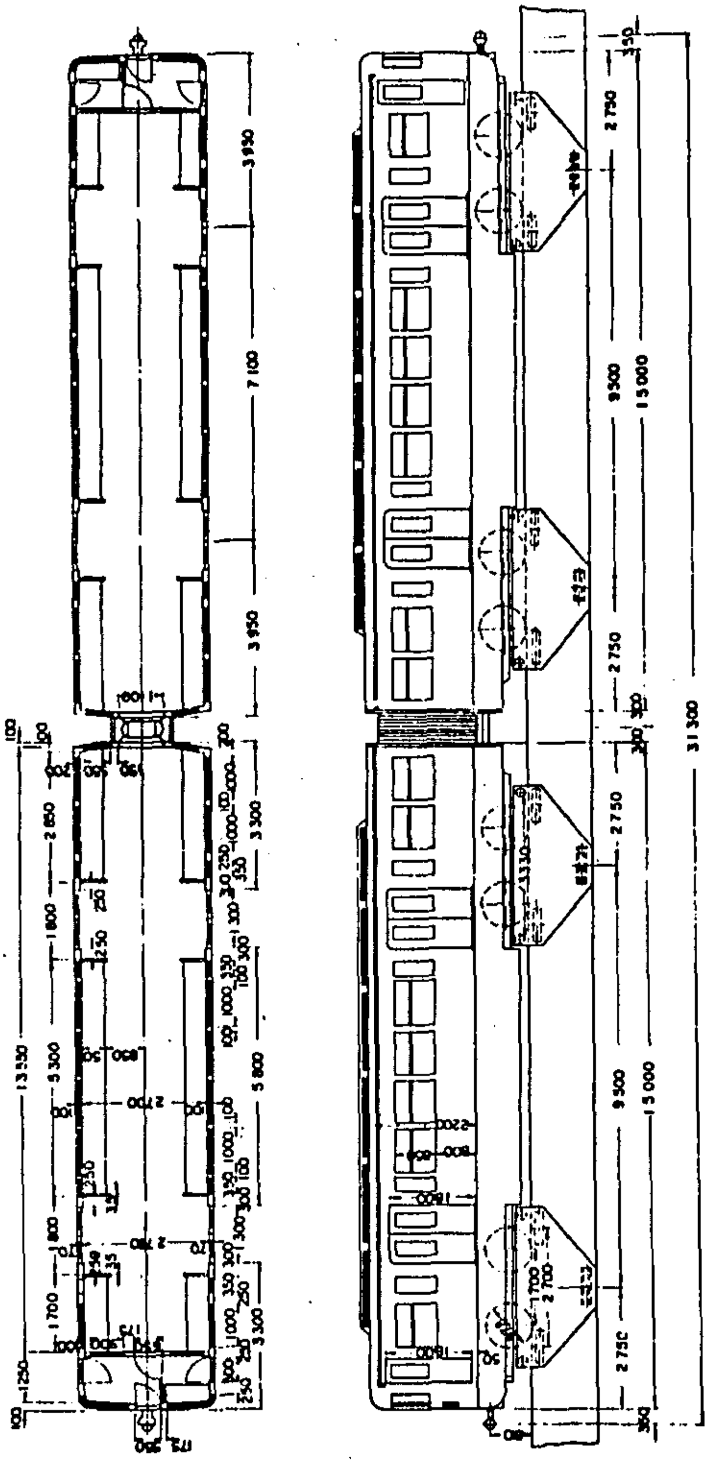
The capacity of a two-rail car is 35% larger than that of a mono-rail car. The schedule speed and train headway being equal, the number of cars required will be 35% greater in the mono-rail system by comparison with the two-rail system, as far as the rolling stock currently in use is concerned.

Fig. 3.1 Rolling Stock Dimensions

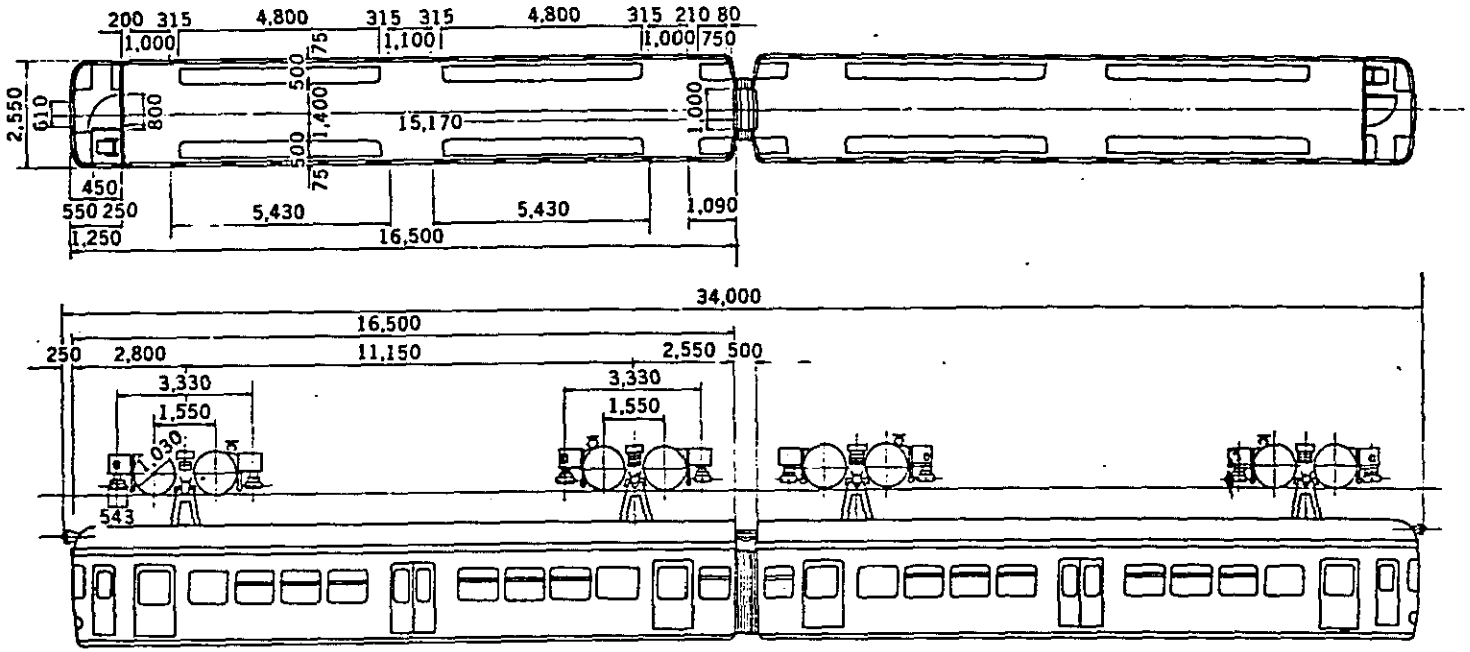
(a) Two-rail System



(b) Saddle Mono-Rail System



(c) Suspension Mono-Rail System



3-3-2 Car Weight and Axle Load

Table 3.3 - Car Weight [tons]

		Car Weight	Total Passenger Weight in Crush Loading	Total
Two-rail		38 (34)	22.06	60.06 (56.06)
Saddle mono-rail	2 doors	25 (23)	15.16	40.16 (38.16)
	3 doors	25 (23)	15.96	40.96 (38.96)
Suspension mono-rail		22 (21)	15.16	37.16 (36.16)

Figures in parentheses indicate the weight of aluminum car.

Table 3.4 - Axle Load [tons]

Two-rail		15	(14)
Saddle mono-rail	2 doors	10.04	(9.54)
	3 doors	10.24	(9.74)
Suspension mono-rail		9.24	(9.04)

The axle load of the two-rail and suspension mono-rail cars present no problem, whereas one tyre of the saddle type mono-rail car weights more than 5 tons, exceeding the load limit of the rubber tyre. In the latter case, therefore, it is necessary to use a light metal like aluminum in the car or adopt a car design which will permit the use of rubber tyres.

If the train is to be equipped with air-conditioning equipment, the car weight increases by about 1.5 tons.

3-3-3 Car Cost

The approximate car costs (export prices as of April 1975) of the three railway systems are shown in Table 3.5.

Table 3.5 - Car Cost (in thousand US$)

	Steel Car (without air-conditioning-equipment	Light Metal Car (with air-conditioning equipment)
Two-rail	370	450
Saddle mono-rail	370	440
Suspension mono-rail	330	410

3-3-4 Number of Car

The passenger capacity and train headway or frequency decides the required train length. (The final train length will be decided in the next study stage.)

3-4 Transport Capacity

The car size and train formation are decided by the forecast traffic demand. The three railway systems will be compared here as to transport capacity, assuming that the cars to be used in the three different railway systems are built to their respective standard dimensions.

Seat depth	550 mm
Depth of driver's cab (excluding the car of suspension mono-rail)	1,700 mm

3-4-1 Floor Area Normal Passenger Capacity and Planned Maximum Passenger Capacity

The floor area is calculated, assuming that the average margin for passengers' knees is 250 mm. Normal passenger capacity calculation is based on the assumption that the average floor area occupied by one standing person is 0.35 m^2 (70 cm x 50 cm). The planned maximum passenger capacity is the number of passengers in the most crowded car in the peak period and is calculated on the assumption that the average floor area occupied by one standing passenger in this state is 0.135 m^2 (45 cm x 30 cm).

Table 3.6 Passenger Capacity

Car		Floor Area (m^2)			Normal Passenger Capacity			Planned Maximum Passenger Capacity		
		Seated	Standing	Total	Seated	Standing	Total	Seated	Standing	Total
Two-rail	End Car	17.61	28.79	46.4	50	82	132	50	213	263
	Intermediate Car	20.24	30.38	50.62	58	86	144	58	225	283
Saddle mono-rail	2 doors	15.36	20.28	35.64	44	57	101	44	150	194
	3 doors	12.78	22.86	35.64	36	65	101	36	169	205
Suspension mono-rail		16.64	19.76	36.4	48	56	104	48	146	194

3-4-2 Crush Capacity

There is no knowing in any way else than by experiment how many passengers a car can carry in excess of its normal passenger capacity. The Japanese National Railways carried out an experiment to determine the crush capacity of a car, but the results obtained in this experiment are of little practical value, because they took time to pack a car, taking no account of the normal dwell time. The number of passengers calculated under the following conditions may be taken as a reasonable crush capacity of a car.

a) Margin for the passenger's knee 150 mm

b) Average floor area per passenger 0.1 m^2 (40 cm x 25 cm)

c) Weight of one passenger (including baggage) 57 kg

Table 3.7 - Crush Capacity

Car		Floor Area (m^2)			Crush Capacity			Load (tons)
		Seated	Standing	Total	Seated	Standing	Total	
Two-rail	End car	15.41	30.99	46.4	50	310	360	20.52
	Intermediate car	17.71	32.91	50.62	58	329	387	22.06
Saddle mono-rail	2 doors	13.44	22.20	35.64	44	222	266	15.16
	3 doors	11.19	24.45	35.64	36	244	280	15.96
Suspension mono-rail		14.56	21.84	36.4	48	218	266	15.16

3-4-3 Train Capacity and Transport Capacity in Peak Hours

The average passenger capacity per train in a 1-hour peak period is placed at 150% of the nominal passenger capacity of the train.

Table 3.8 Transport Capacity in Peak Period

Car		Train Formation	Nominal Passenger Capacity			Average Passenger Capacity per Train in 1-hour Peak Period			Planned Maximum Passenger Capacity		
			Seated	Standing	Total	Seated	Standing	Total	Seated	Standing	Total
Two-rail		6 cars	316	500	816	316	908	1224	316	1302	1618
Saddle mono-rail	2 doors	8 cars	352	456	808	352	860	1212	352	1200	1552
	3 doors	8 cars	288	520	808	288	924	1212	288	1352	1640
Suspension mono-rail		8 cars	384	448	832	384	864	1248	384	1168	1552

The two-rail train is assumed to consist of 6 cars or 2 units which respectively comprise Tc, M and Mc, and Mc, M and Tc, whereas the mono-rail train, 8 cars or 4 units which all comprise Mc and Mc, as shown in Figs. 3.1(b) and 3.1(c).

Two-rail	20 m x 6 cars = 120 m
Saddle mono-rail	31.3 m x 4 units = 125.2 m
Suspension mono-rail	34 m x 4 units = 136 m

The passenger capacity determined by the car size can be considered much the same between the two-rail train and the mono-rail train, and the two-rail train hardly differs in length from the saddle mono-rail train, but the suspension mono-rail train is slightly longer than the two-rail train.

The transport capacity of one train has been compared between the two-rail system and the mono-rail system, but the line capacity largely depends on the actual schedule speed and train headway. Planning transport capacity, therefore, requires a further detailed study.

3-5 Construction Criteria

The construction criteria of the mono-rail and two-rail systems are summarized in Table 3.9.

The major differences in construction criteria between the two-rail and mono-rail systems are the minimum curve radius and maximum gradient. In the Manila RTR Line No. 1, however, the minimum radius curve occurs only in Quezon Boulevard and Taft Avenue. In other words, this line has little cost-reducing factors as far as curves are concerned, even if the mono-rail system is adopted. Furthermore, sharp curves dictate a reduction in train speed. The same thing can be said of the gradient Line No.1 may be built at a steep grade, but its construction cost will not be affected to any extent.

Table 3.9 Construction Criteria

Item		Two-rail	Saddle Type Mono-rail
Track Gauge		1.435^m	-----
Power Supply System		Third rail system	-----
Power Supply		D.C. 750V	D.C. 750V
Car Gauge (Width x Height)		$2.88^m \times 4.00^m$	$2.95^m \times 3.70^m$
Construction Gauge		$3.28^m \times 4.30^m$	$3.87^m \times 3.85^m$
Car Length		20 m	15.65 m
Minimum curve radius	Main line	200^m (160^m)	120^m (60^m)
	Side line	120 m	-----
	Turnout	150 m	94 m
	Along a Platform	500^m (300^m)	Straight line (200 m)
Length of transition curve		$L \geqq 300C$, where the curve radius is less than 800 m	300 C
Distance between reversed transition curves		Not less than 15^m	Not less than 15^m
Cant		$C = 11.8\frac{V^2}{R}$ 150^{mm}	Maximum 0.12 (tan 0)
Maximum gradient	Main line	35/1000	60/1000
	Side line	40/1000	-----
	At a Platform	10/1000	10/1000
Minimum gradient of underground section		2/1000	2/1000

Item	Two-rail	Mono-rail
Minimum radius of vertical curve	Not less than 2000^{m} in a section where the variation in gradient exceeds 10/1000	Not less than 500^{m} in a section where the variation in gradient exceeds 5/1000
Expansion of construction gauge at curve section	$W = \frac{24,000}{R}$, where the curve radius is less than 800^{m}	$W = \frac{12,000}{R}$, where the curve radius is less than 800^{m}
Gauge widening	$S = \frac{2,250}{R}$ 25^{mm}, where the curve radius is less than 600^{m}	------
Height from rail level to formation level	Concrete bed: 500^{mm} ballast bed: 700^{mm}	------
Minimum track - center distance	3.80^{m}	3.70^{m}

Note: 1. The curve radii can be reduced to the values shown in parentheses, if absolutely necessary.

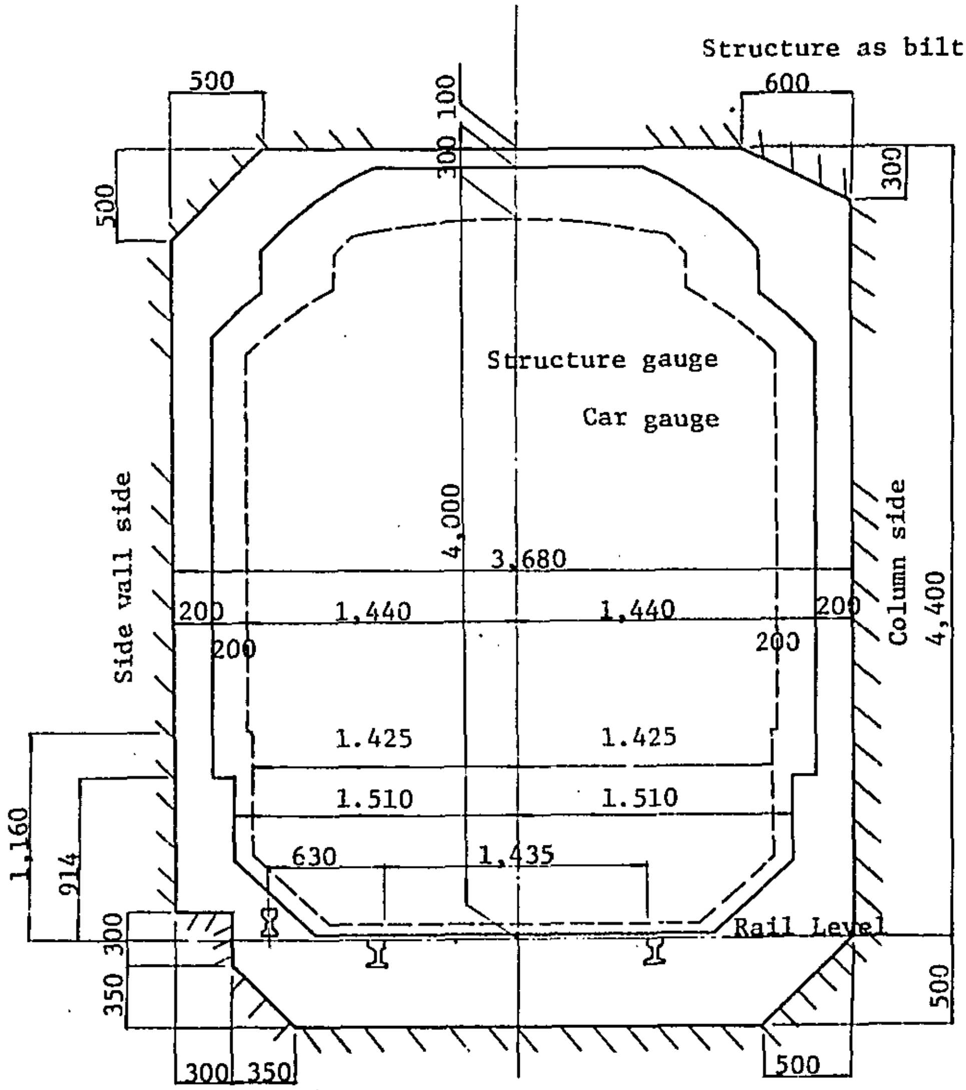
2. Minimum center track distances in the elevated section are as follows:

Main line : 3,600 mm

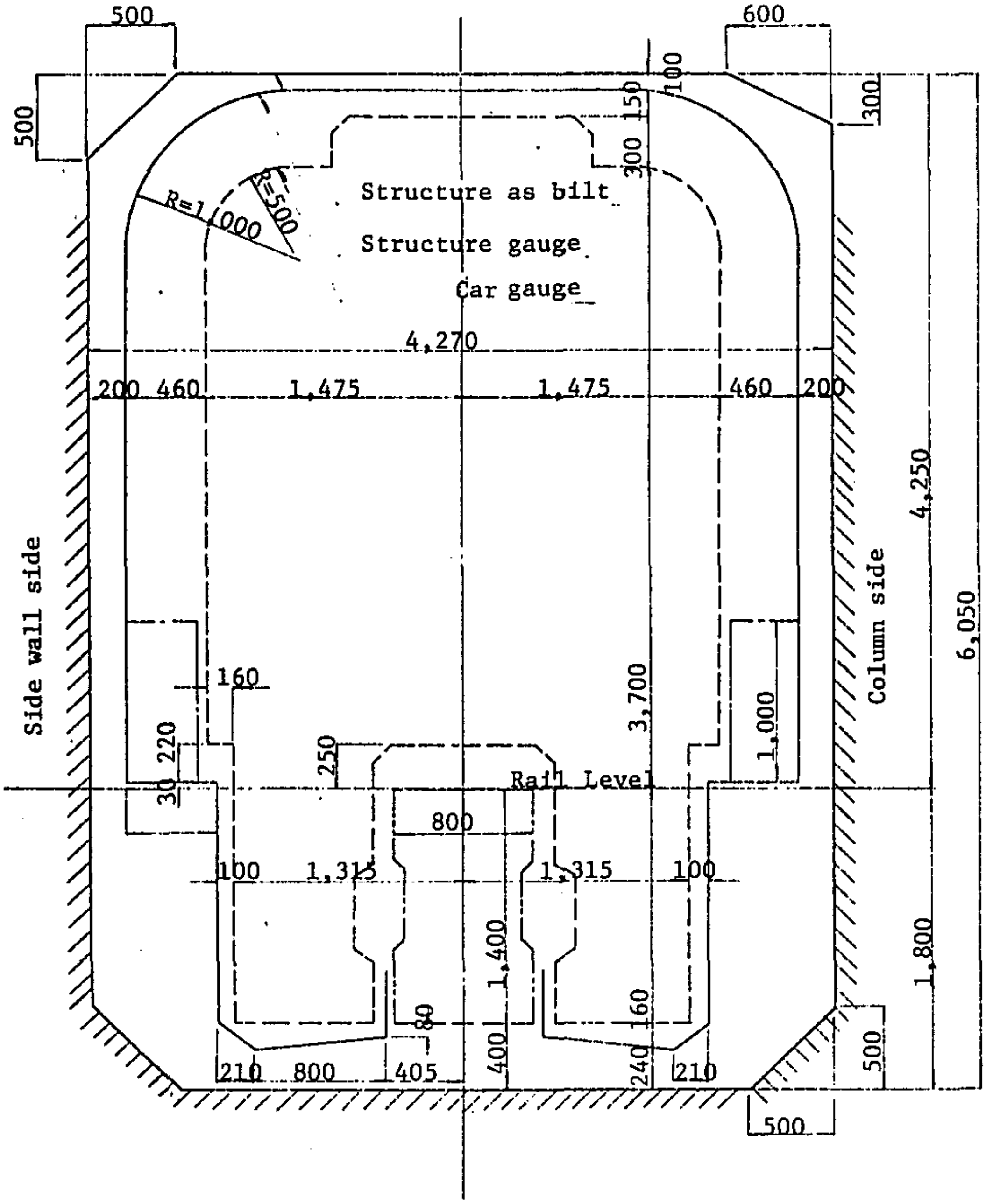
Side line : 3,400 mm

Fig. 3.2 - Structure and Car Gauge

(a) Two-rail System



(b) Mono-rail System (Saddle Type)



Three car sizes are used in the urban mono-rail system: large, medium and small.

Table 3.10 - Dimensions of Saddle Mono-rail Cars (mm)

Item \ Size	Large	Medium	Small	Remarks
Car length	15 000	12 500	6 200	
Two-car formation length	31 300	26 200	13 350	Distance between couplers
Maximum car width	2 940	2 440	1 800	
Maximum car height	3 590	3 540	2 600	Height from top-of-rail level
Car body height	4 770	4 720	3 300	
Distance between bogies	9 500	7 300	4 000	
Wheel base	1 700	1 500	1 500	
Weight (tons)	25	18	6	Empty

3-6 Railway Structures

3-6-1 Route

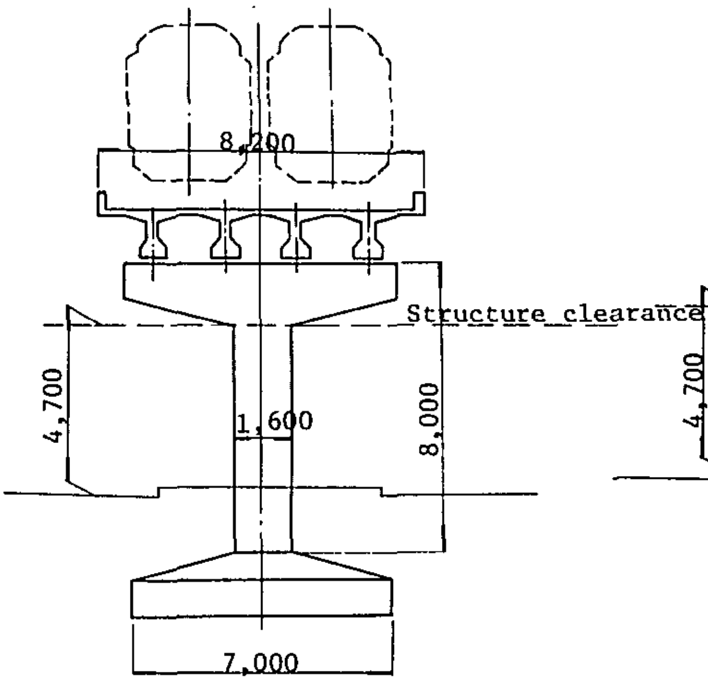
The route features little differs from the mono-rail system to the two-rail system, except for slight differences in grade and curvature in part of the line.

3-6-2 Condition for Comparison of Structures

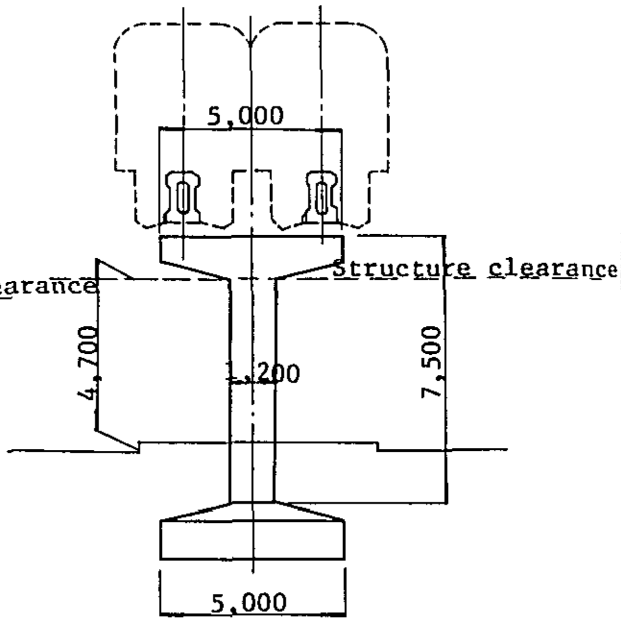
The underground railway is generally 2 to 3 times more expensive to construct than the elevated railway, depending on the conditions of the construction site.

Figure 3.3 Typical Cross Section

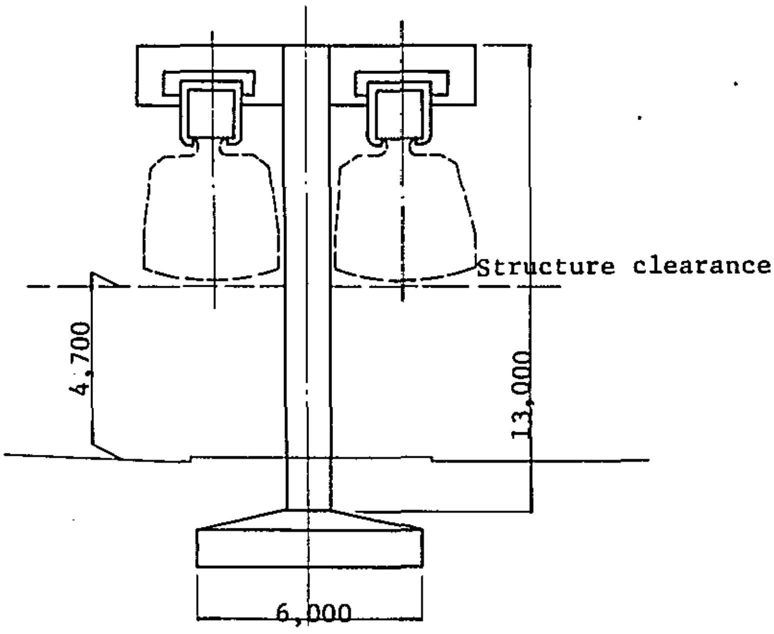
(a) Two-rail



(b) Saddle Mono-rail



(c) Suspension Mono-rail



The elevated railway on the other hand, may disturb street traffic because it is built on top of columns set in streets. Furthermore, the elevated structure can hardly merge into the landscape and presents other environmental problems.

These problems will be discussed in detail later. For the present, it should be noted that the comparison of the two different railway systems is made based on the assumption that they are to be built with the same structure in order to provide directly comparison under the same conditions.

There is no iron-bound rule which requires that the mono-rail be elevated and the two-rail be underground. Accordingly, the assumption is made here for comparison purpose that the mono-rail and two-rail systems are at the same level, either underground or elevated, which is realistic and reasonable assumption in the case of the Rapid Transit Railway Line No. 1.

3-6-3 Standard Elevated Structure

The standard elevated structures of the mono-rail and two-rail systems are shown in Fig. 3.3.

The mono-rail track is laid on top of a main prestressed concrete girder or suspended from it, whereas the two-rail track is laid on the roadbed built with a main prestressed concrete girder and cast-in-place concrete. The cross section of the column for two-rail track measures 1.6 m by 1.6 m, and that of the girder for mono-rail track, 1.2 m by 1.2 m.

The elevated structures for the two-rail and mono-rail systems are compared in Table 3.11.

Table 3.11

Comparison of Standard Elevated Two-rail and Mono-rail Structure

[per 20 m]

Item			Unit	Two-rail	Mono-rail	
					Saddle Type	Suspension Type
Width of structure			(m)			
Concrete	Main girder	P.C.	(m^3)	81.1	57.6	-
		Cast-in-place concrete	(m^3)	10.0	-	-
	Pier		(m^3)	36.7	18.6	33.3
	Foundation		(m^3)	64.6	33.1	33.1
Exeavation			(m^3)	329.1	212.3	212.3
Roadbed			(m^3)	94.2	-	-

The construction cost for one meter of track is as follows:

Two-rail US$4,300
Saddle Mono-rail US$2,500

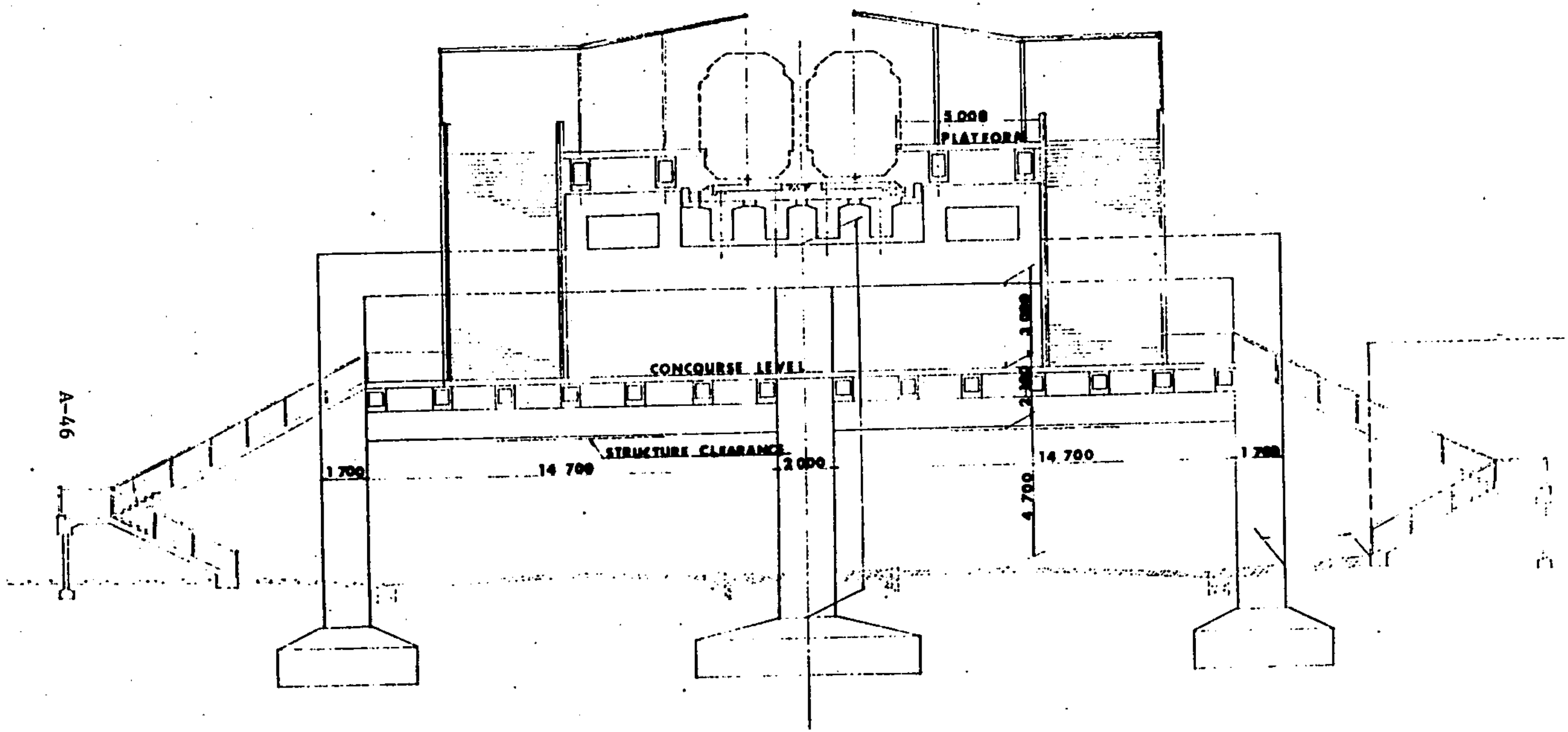
Mono-rail track is cheaper to build than two-rail track, as far as the elevated structure is concerned. The construction costs calculated above are approximate, but serve the purpose of comparison.

3-6-4 Standard Elevated Stations

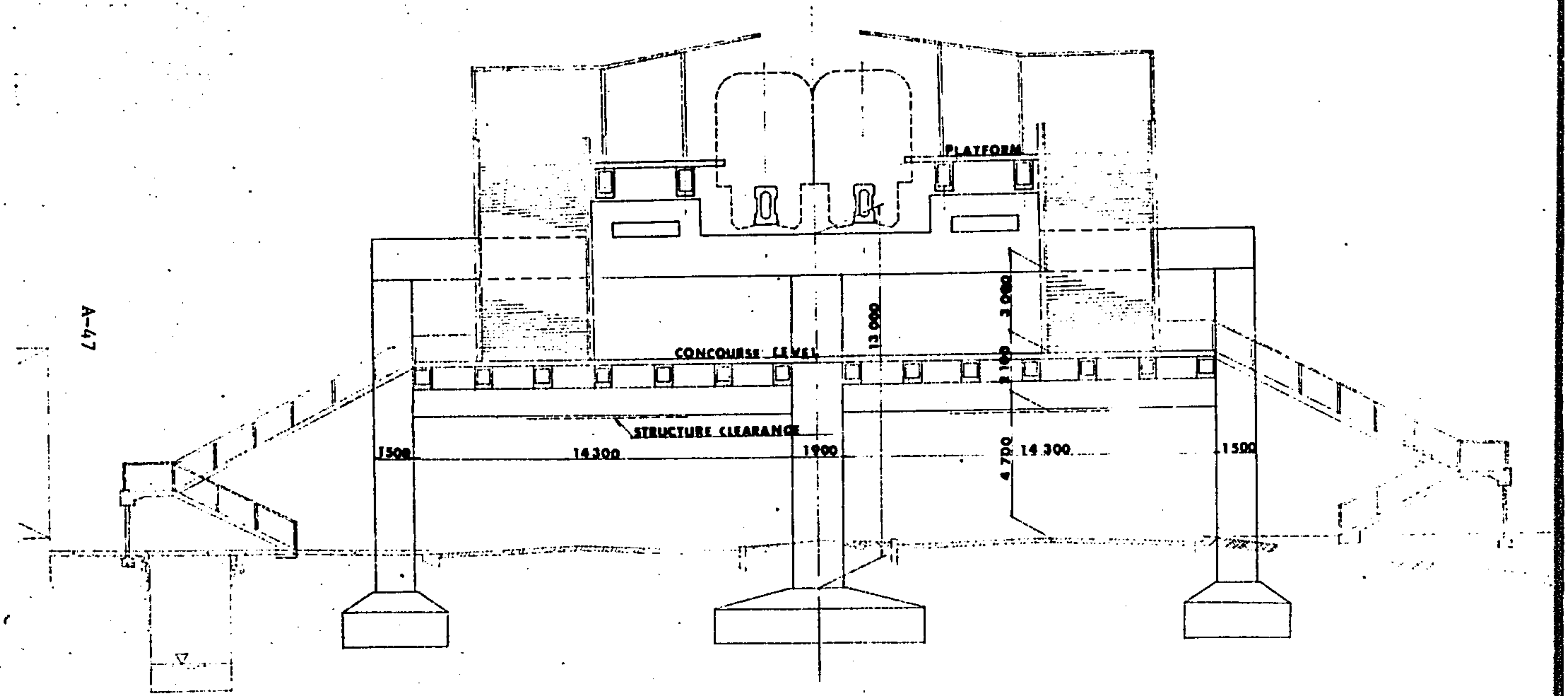
The train length decides the length of station. The required station length is 130 m in the two-rail system and 135 m in the mono-rail system. The station is connected to the surface by a concourse and an office and electric and machinery rooms are built at the center of the station. The standard station structures are shown in Fig. 3.4, and the standard specifications of elevated stations, in Table 3.12.

Fig. 3.4 Standard Elevated Station

(a) Two-rail System



(b) Saddle Mono-rail System



(c) Suspension Mono-rail System

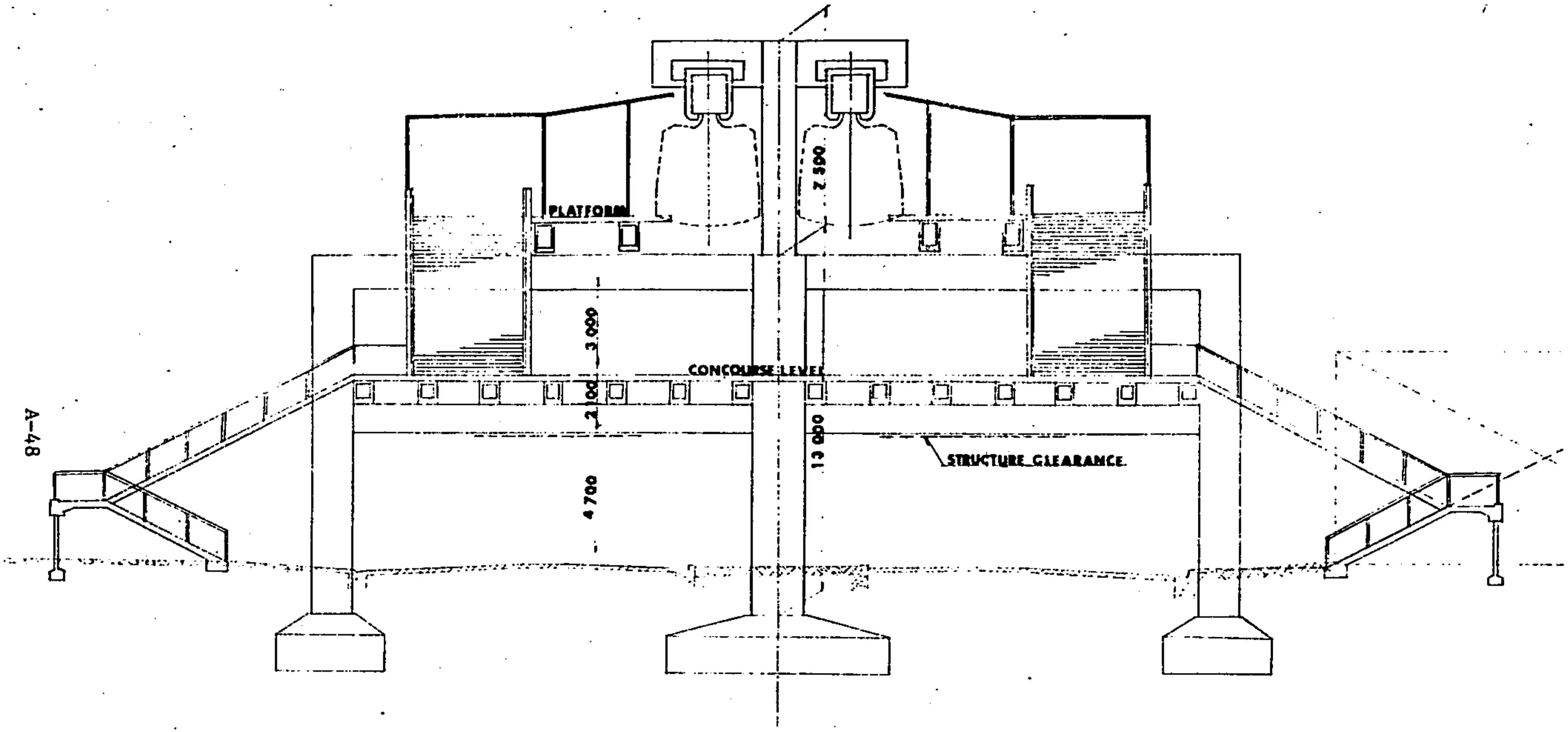


Table 12. - Comparison of Standard Elevated Stations

[per 20 m]

Item			Unit	Two-rail	Mono-rail	
					Saddle Type	Suspension Type
Width of station			(m^3)			
Concrete	Main girder	P.C.	(m^3)	81.1	57.6	-
		Cast-in-place concrete	(m^3)	10.0	-	-
	Platform	P.C.	(m^3)	38.2	38.2	38.2
		Cast-in-place concrete	(m^3)	52.8	52.8	52.8
	Concourse	P.C.	(m^3)	100.8	100.8	100.8
		Cast-in-place concrete	(m^3)	144.2	144.2	144.2
	Pier		(m^3)	212.7	181.4	202.0
	Foundation		(m^3)	237.4	195.8	195.8
Excavation			(m^3)	880.7	750.7	750.8
Roadbed			(m^3)	94.2	-	-

The construction cost for one meter of the station structure is as follows:

Two-rail US$12,500

Mono-rail US$10,500

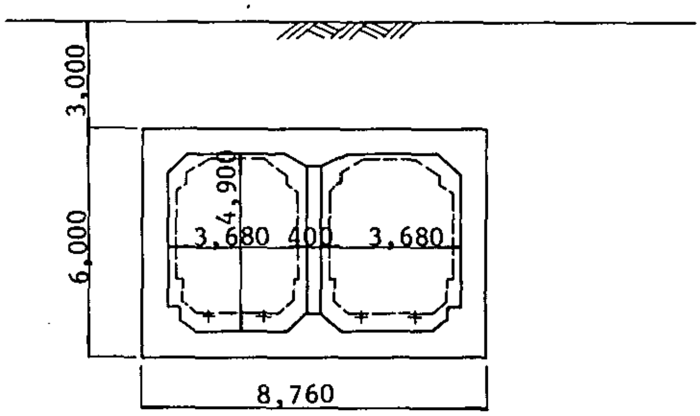
In the cost comparison above, the assumption is made that there is little or no difference in station structure and dimension between the two-rail and mono-rail systems.

3-6-5 Standard Box-section Tunnels

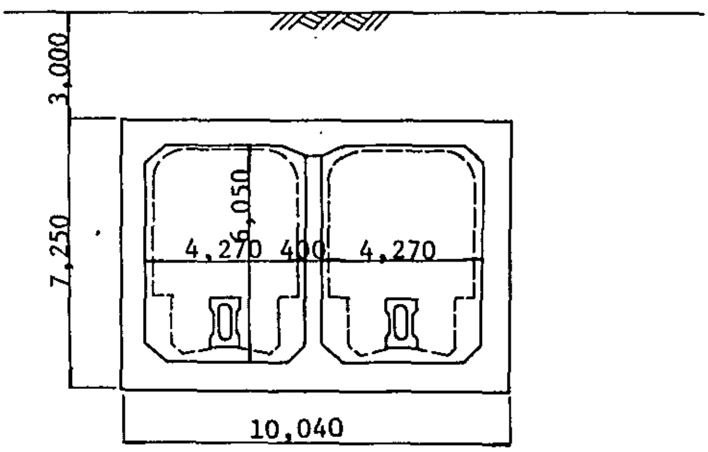
Assuming that the earth covering is 3 m thick, the structures of the box-section tunnels for two-rail and mono-rail tracks are as shown in Fig. 3.5.

Fig.5 Typical cross section

(a) Two-rail System



(b) Saddle Mono-rail System



(c) Suspension Mono-rail System

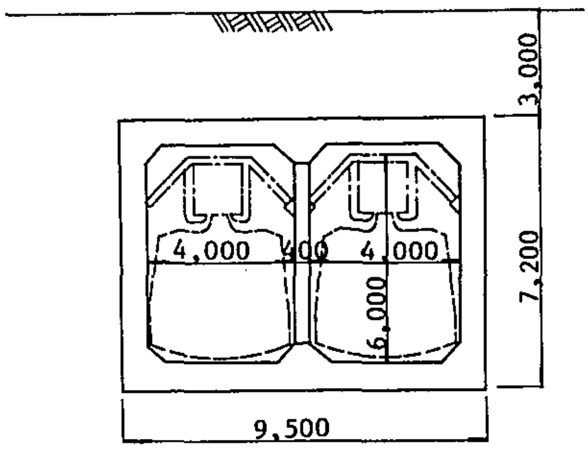


Table 3.13 Comparison of Standard Box-section Tunnels

[per 1 m]

	Two-rail	Saddle Mono-rail	Suspension Mono-rail
Tunnel width	8.76 m	10.04 m	9.50 m
Tunnel height	6.00 m	7.20 m	7.25 m
Volume of Excavation	84.2 m^3	109.1 m^3	103.0 m^3
Volume of concrete	16.2 m^3	20.5 m^3	19.8 m^3
Other	Materials Roadbed	Track girder	Track suspension

The construction cost for one meter of the structure is as follows:

Two-rail	US$10,100
Mono-rail	US$13,500

As can be known from Table 3.13, the Two-rail tunnel is less expensive to built than the Mono-rail tunnel for a standard tunnel section.

Since about 10.5 km of the total route length of Line No. 1 is planned to go underground, this difference in tunnel construction cost is an important consideration in the selection of the Two-line system or the Mono-rail system.

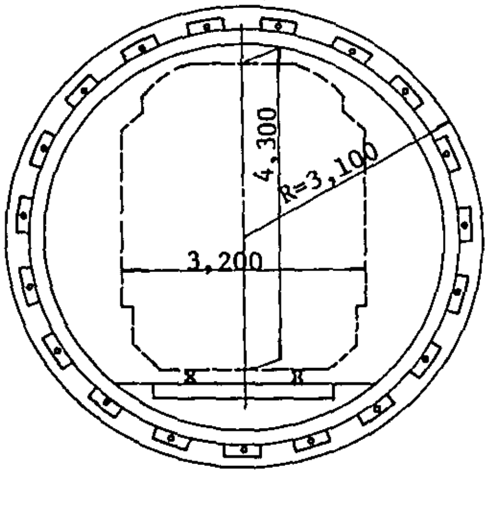
3-6-6 Standard Circular Tunnels

The construction gauge decides the cross section of the standard circular tunnel as shown in Fig. 3.6.

The circular tunnel is, in general practice, built by the shield method, and its permanent lining is reinforced concrete segments. According to the plan, circular tunnels are to be built under the Pasig river and the road near Far Eastern University.

Fig. 3.6 Typical cross section

(a) Two-rail System



(b) Saddle Mono-rail System

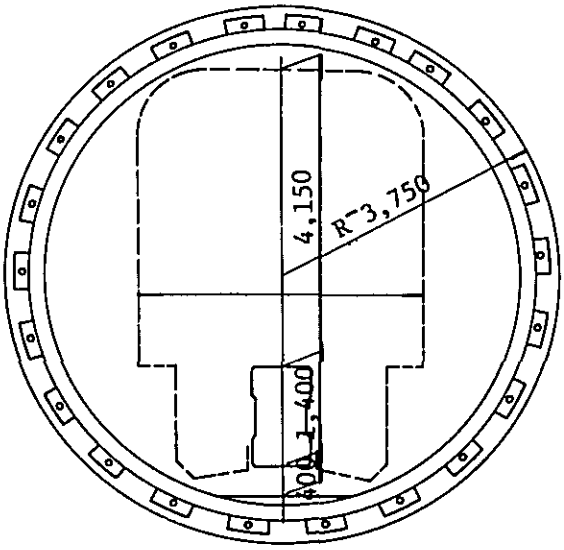


Table 3.14 Comparison of Standard Circular Tunnels

Item	Two-rail	Saddle Mono-rail
External diameter of tunnel	6.20 m	7.50 m
Volume of excavation	30.2 m^3	44.2 m^3

The construction cost for one meter of tunnel is as follows:

Two-rail US$24,600

Mono-rail US$36,000

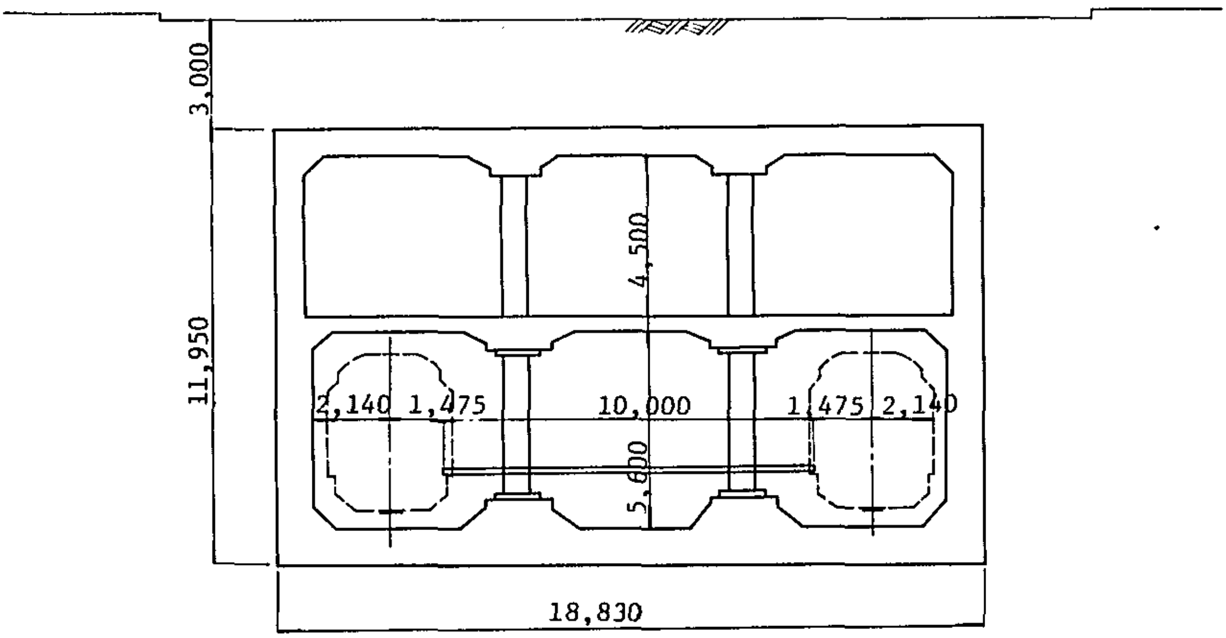
The two-rail system is more advantageous also in a circular tunnel construction.

3-6-7 Standard Underground Stations

The cross section of standard underground station is shown in Fig. 3.7. Both the two-rail and mono-rail underground stations are of the same size at concourse level, but the open space inside the structure differs between the two-rail station and the mono-rail station on account of a difference in car size, although the platforms of both the stations are of the same width.

Figure 3.7 Typical cross section

(a) Two-rail System



(b) Mono-rail System

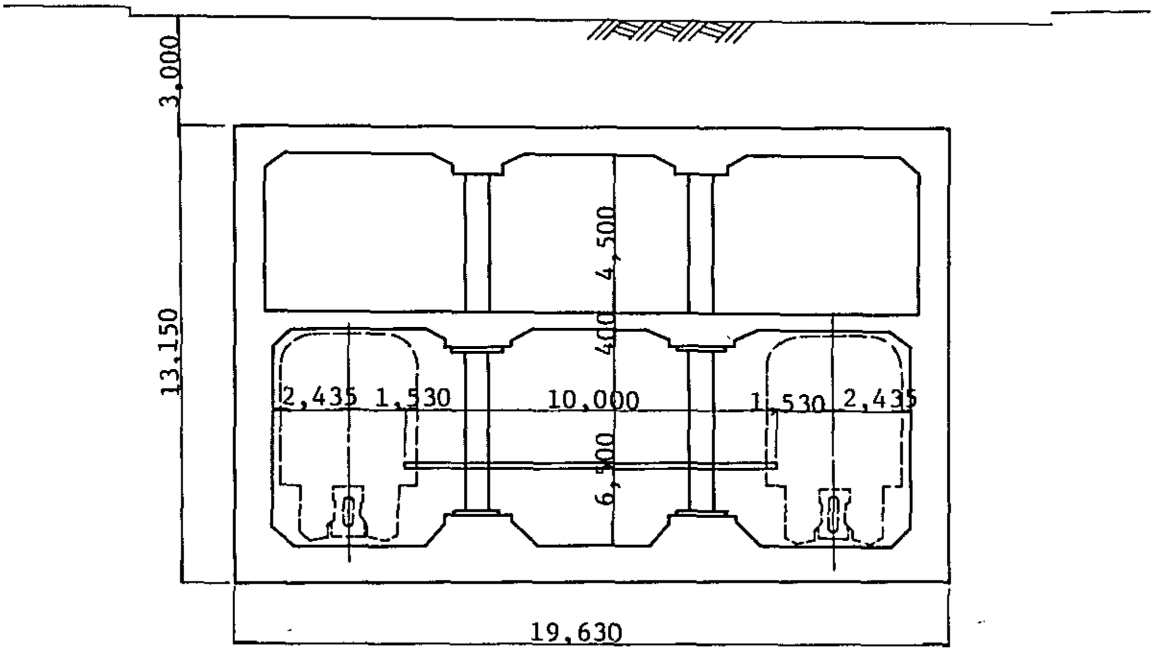


Table 3.15 Comparison of Standard Underground Stations

[per 1 m]

Item	Two-rail	Saddle Mono-rail
Station length	125.0 m	125.5 m
Station width	18.88 m	19.63 m
Station height	11.95 m	13.15 m
Volume of Excavation	308.8 m^3	345.5 m^3
Volume of Concrete	62.8 m^3	67.2 m^3

The construction cost for one meter of station is as follows:

Two-rail	US$38,000
Mono-rail	US$42,500

The two-rail system is more advantageous also in underground station construction.

3-7 Depot

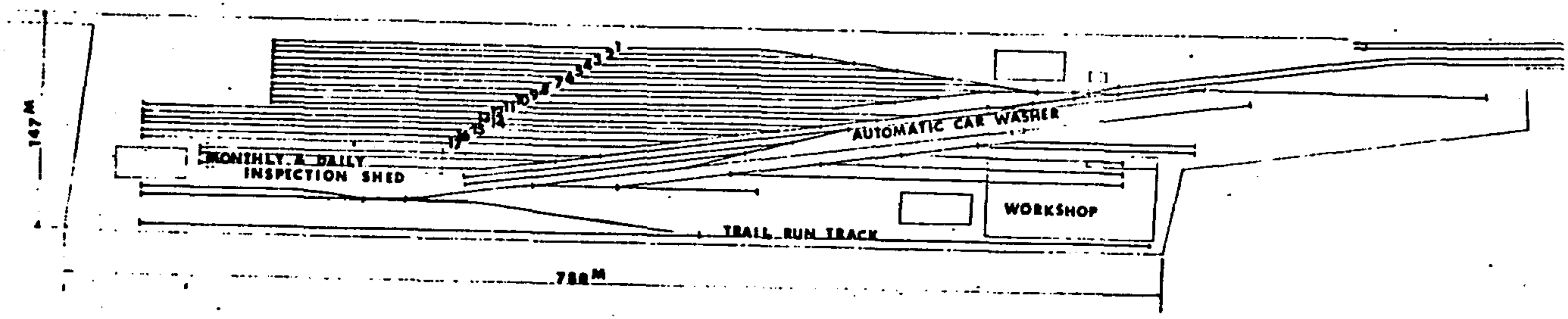
The car depot facilities do not differ from the mono-rail system to the two-rail system. As the turnout used in mono-rail track presents problems because of frequent failure, the number of turnouts will necessarily increase, which is contrary to the aim of minimizing the number of turnouts as much as possible.

If a moderate number of cars are used, the track layout may be in the form of a loop in the car depot. In the case of the Manila Rapid Transit Railway, however, the loop track will present many technical problems from the point of the land available, because as many as 400 cars are to be accommodated.

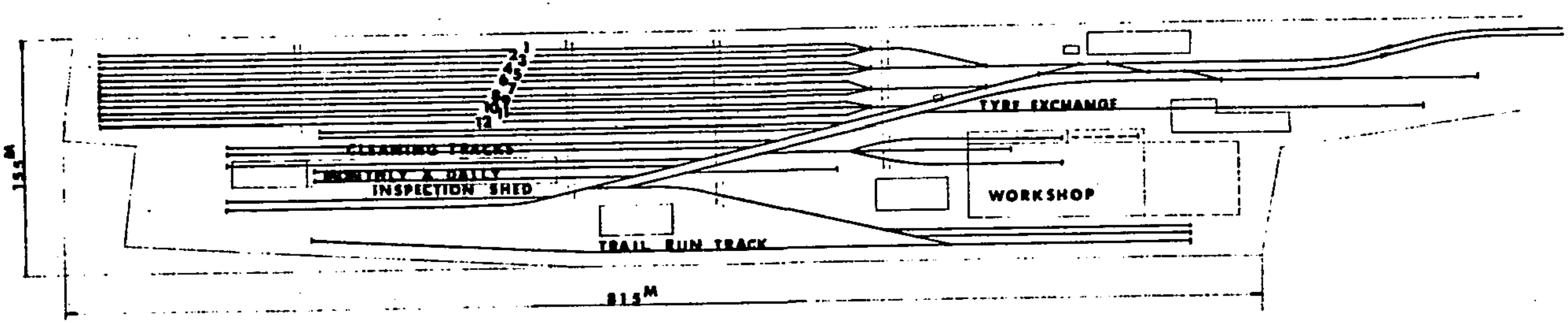
Since the mono-rail track girder will come to 1.4 m in height, it is necessary to build underpasses for inspection and maintenance in the car depot. Taken altogether, the car depot favors the two-rail system.

Fig. 8 Depot Track Arrangement Plan

(a) Two-rail System



(b) Mono-rail System



3-8 System of Supplying Electric Power and Electric Installations

Electric traction is applied in both two-rail and mono-rail systems. The system of supplying electric power used in the two-rail system is generally AC 25 KV and DC 3,000 V. 1,500 V or 750 V. The mono-rail system is generally operated on DC 750 V.

In either system, the motors are driven by DC 375 V or DC 750 V. If AC 25 KV is received, the power is reduced to an operating voltage by a car-mounted transformer and rectified by a car-mounted silicon rectifier.

In the case of RTR Line No. 1, DC 750 V third-rail systems is most recommendable for the two-rail system in consideration of traffic volume, train speed and inductive interference on telecommunication lines as well as tunnel construction costs.

Hence, for comparing two-rail and mono-rail systems, it is assumed that DC 750 V will be used in both systems.

3-8-1 *Power for Electric Traction*

The power required for electric traction depends on the station spacings, track curvature, track grade and car performance characteristics. According to showings of the Tokyo Haneda Monorail and other mono-rails, it is known that the mono-rail *system requires more power than two-rail system.*

3-8-2 Transmission Line for Service

The rapid transit railway consumes a very large amount of electric power, and should a power failure occur, all the trains will come to a stop, causing anxiety to the passengers especially in an underground section. Necessarily, electric power must be delivered from large capacity substations where there are little voltage fluctuation and no power failure. Furthermore, provisions will be made to supply power from other substations in case of a failure of one substation.

If DC 750 V is to be used in RTR Line No. 1, it is necessary to build traction substations at about 2 km intervals. Since it will be difficult for each traction substation to receive power separately from MERALCO substations, the electric power will be delivered to three or four traction substations and connecting transmission lines will be provided to supply power from there to other traction substations.

i) Connecting Transmission Line

In the case of the two-rail system, the transmission lines will be laid in troughs built along the sidewalls as shown in Figure 3.9(a), whether elevated or subsurface. Thus, the transmission lines can be laid easily and economically.

The transmission lines for the mono-rail system will be laid in the same way in underground section, but will have to be accommodated on racks built under the girder as shown in Figure 3.9(c). Thus, higher cost is required for installation.

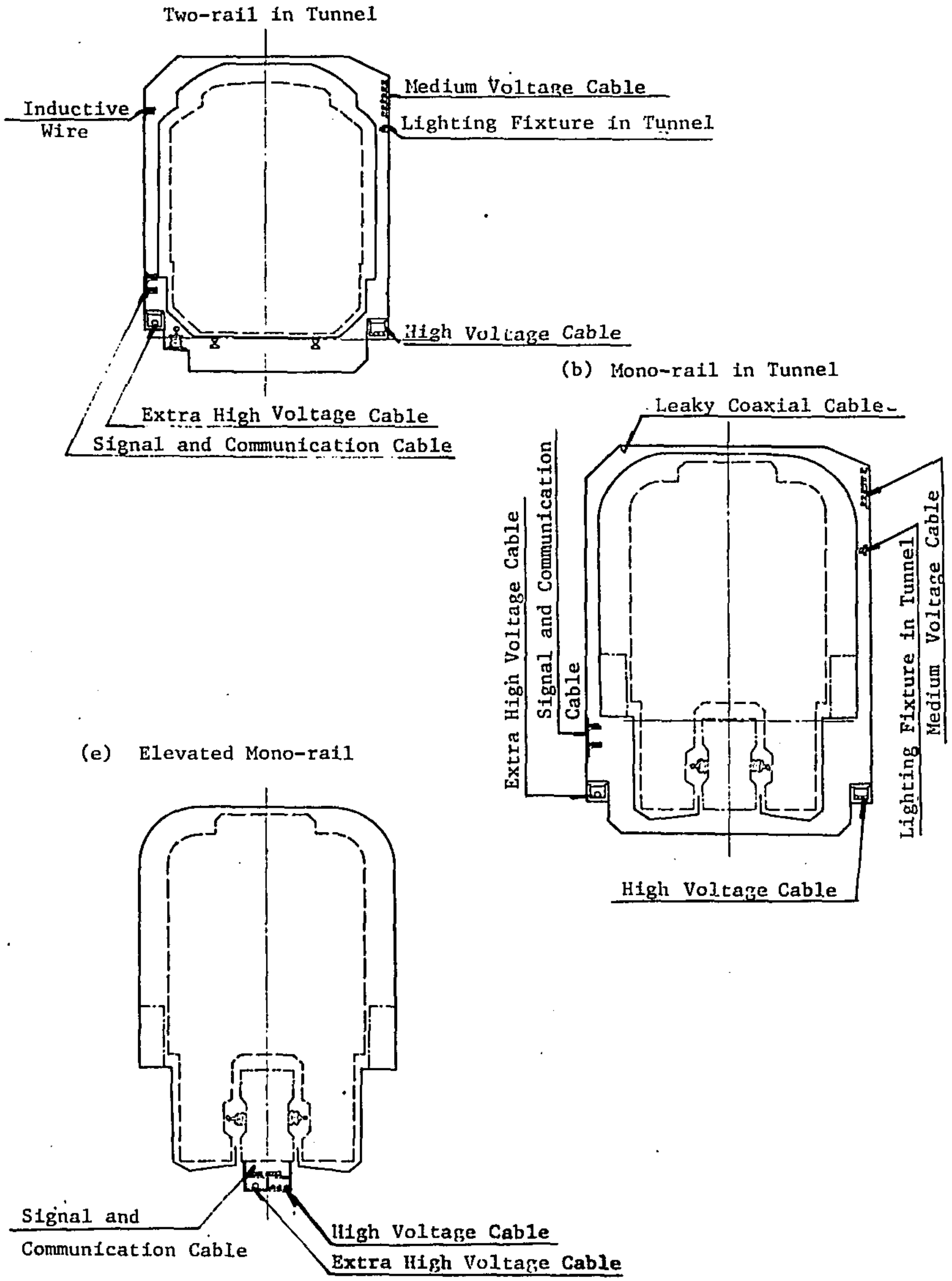
3.8.3 Traction Substation

As the mono-rail consumes more power than the two-rail system, larger capacity transformers and silicon rectifiers will be required. The power equipments of all the traction substations will be remotely controlled and supervised from the electric power control center regardless of the system adopted.

3.8.4 Contact system

In the two-rail system,power is supplied from the third

Figure 3.9 General Arrangement of Electrical Facilities



rail and the running rail. As the third rail is supported on insulators fixed on sleepers as shown in Figure 3.9(a), its construction is simple.

Since mono-rail system does not use conductive track, two contact lines (positive and negative) will have to be installed one on each side of the mono-rail girder. Hence, the mono-rail system will require more manpower for maintenance insofar as contact line is concerned.

3-9 Signaling and Telecommunication

3-9-1 Turnout

In two-rail system, the turnouts are of simple construction and the switches are standardized. They are easy to maintain and repair.

The turnouts for suspension mono-rail (SAFEGE type, etc.) are of a simple construction and seem to be easy to manufacture, but the turnouts for saddle type mono-rail are complex in construction and there is little experience in their practical use.

At present, there are showings on turnout operation in 6 minute headway, although it is claimed that the headway can be shortened to about 3 minutes.

3-9-2 Signaling

In the case of two-rail system, a system of continuous train control is adopted whereby a train entering a signal block section is detected by relay function due to the short circuiting the two-rails by train axles.

On the other hand, in mono-rail system, two contact lines (positive and negative) cannot be used as track circuits. However, by using two conductors for the return (negative) contact line and short-circuiting them with negative pantograph, a similar system to that in two-rail can be adopted for train control although it will be more costly.

Hence mono-rail generally employs check-in/check-out block system. In this system, a train is checked with high-frequency wave assigned for check-in when it enters a block section and the existence of the train in that section is confirmed with relay function, and checked with high-frequency wave assigned for check-out when leaving the section, and again the existence of the train in the next block section is confirmed by checking in the same way. Without any of these three confirmations, the succeeding train will be stopped to prevent malfunctioning. Although there is a slight feeling of uneasiness, this system is adopted in Tokyo Haneda Monorail with satisfactory results.

In both the two-rail and mono-rail systems, the train operation on the entire line will be controlled and supervised by a train dispatcher through CTC.

3-9-3 Telecommunication

(1) Telecommunication Lines

In railway operation, many telecommunication lines are required to provide communications among the train operation control cetner, the electric power control center, controlled traction substations, maintenance units, stations and trains.

In the two-rail system, the telecommunication lines can be easily laid along the sidewall, whether the track is underground or elevated.

In the elevated mono-rail system, the telecommunication cables are placed on racks built under the girders, but provision must be made to protect them from high voltage in the case of transmission and distribution line faults and prevent misinformation due to inductive interference.

(2) Train Radio Telephone

Train radio telephone is provided so that the train crew and the train dispatcher can readily contact each other to maintain accurate train operation and take pertinent measures promptly in case of abnormalities.

In the two-rail system,an inductive carrier system is generally used, and wires for this system are installed on the upper part of the tunnel sidewall (see Figure 3.9(a)). This telecommunication system is simple and easy to install.

In the mono-rail system, space radiation system seems well suited for this purpose. If the use of two or three radio bands is permitted, there will be no problem, but if only one band is assigned, only one-way communication can be provided. In this case, it is difficult to provide separate communication for up-track and down-track. If the mono-rail goes underground, it is necessary to use a leaky co-axial cable to cope with wave reflection and attenuation.

3-10 Land

To build an urban mass transit system, it is necessary to secure land, either temporarily or permanently.

3-10-1 Underground Tunnel

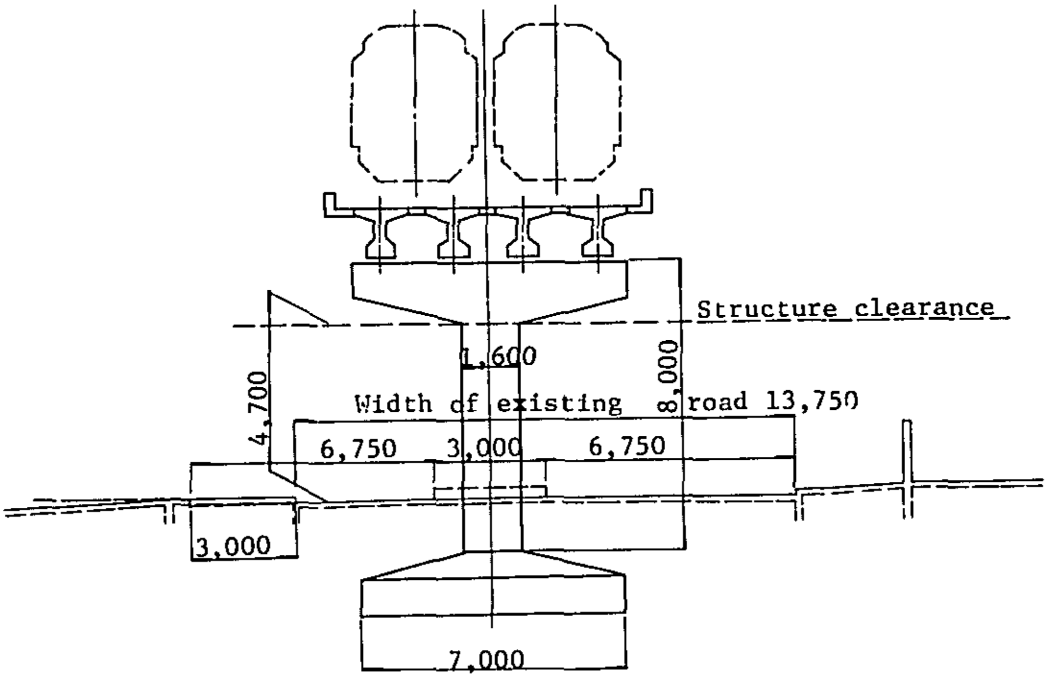
If the railway, whether mono-rail or two-rail, goes underground, it is not necessary to acquire land permanently but only temporarily during tunnel construction.

The required width of the land strip is as follows:

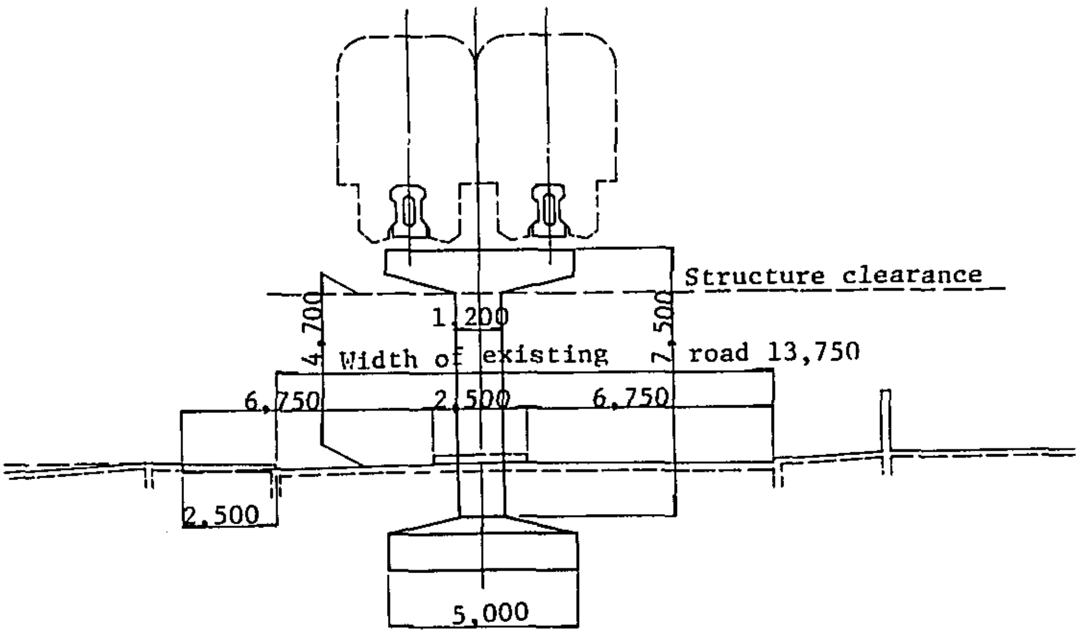
	Two-rail	Mono-rail
Standard Tunnel	9.16	10.44
Standard Tunnel Station	18.80	19.63

Figure 10.- Typical Cross Section of Elevation Schedule along Taft Avenue

(a) Two-rail System



(b) Mono-rail System



3-10-2 Elevated Railway

If the railway is to be elevated, the land to erect columns at the center of the roadway or the median strip is necessary. If the entire length of Line No. 1 is to be elevated, Taft Avenue presents a problem for lack of the median strip, although Quezon Boulevard has a median strip of sufficient width for that purpose.

In this case, it will be necessary to acquire a strip of land over the entire length of Taft Avenue. The width of land acquisition along Taft Avenue is estimated as follows:

	Two-rail	Mono-rail
Elevated railway	3.0 M	2.5 M
Elevated station	-	-

The median strips required for the two-rail and mono-rail systems may be seen from the typical cross section as shown in Figure 3.10.

3-11 Safety

The safety to be considered here is not the safety of railway equipment and facilities including cars, but the safety of passengers to be ensured in case of an accident. The factors associated with this kind of safety will be compared here between the two-rail and mono-rail systems.

In the mono-rail system, the car floor is more than 10 m high above ground surface. In this situation, careful consideration should be given to the safe evacuation of passengers in an emergency.

3-11-1 Evacuation at High Level

(1) The troubled train is move to the nearest station to evacuate the passengers.

(2) A rescue train is dispatched to the troubled train to take over its passengers and carry them to the nearest station. In this case, the passengers can be rescued in one of the two methods.

(a) A rescue train is connected to the troubled train on the same track to take over its passengers.

(b) A rescue train is stopped on the opposite track to the troubled train to take over its passengers.

3-11-2 Evacuation to the Ground

(1) The passengers are evacuated by means of emergency equipment carried on board the cars.

(a) Cloth chute

(b) Evacuator

3-11-3 Rescue from the Ground

(1) The passengers are helped out the troubled cars from the ground.

(a) Extension ladder

(b) Fire snorkel

(c) Evacuation by Special Rescue Cars

In the mono-rail system, evacuation of passengers in an emergency requires the employment of various methods, because the track has no roadbed but consists of only one row of longitudinal girders.

In the case of the two-rail system, on the other hand, the roadbed permits the passengers to alight on the track in an emergency.

In the mono-rail system, the passengers may be evacuated by an extension ladder, a fire snorkel or a rescue car, whichever available at the moment. But, depending on the urgency of the situation, it may happen that it comes to the rescue of passengers too late. On top of that, the extension ladder and chute may not provide an efficient means to evacuate the passengers in the limited time, depending on the situation. When all these safety factors are taken into account, the two-rail system is perferred to the mono-rail system from the standpoint of passenger safety.

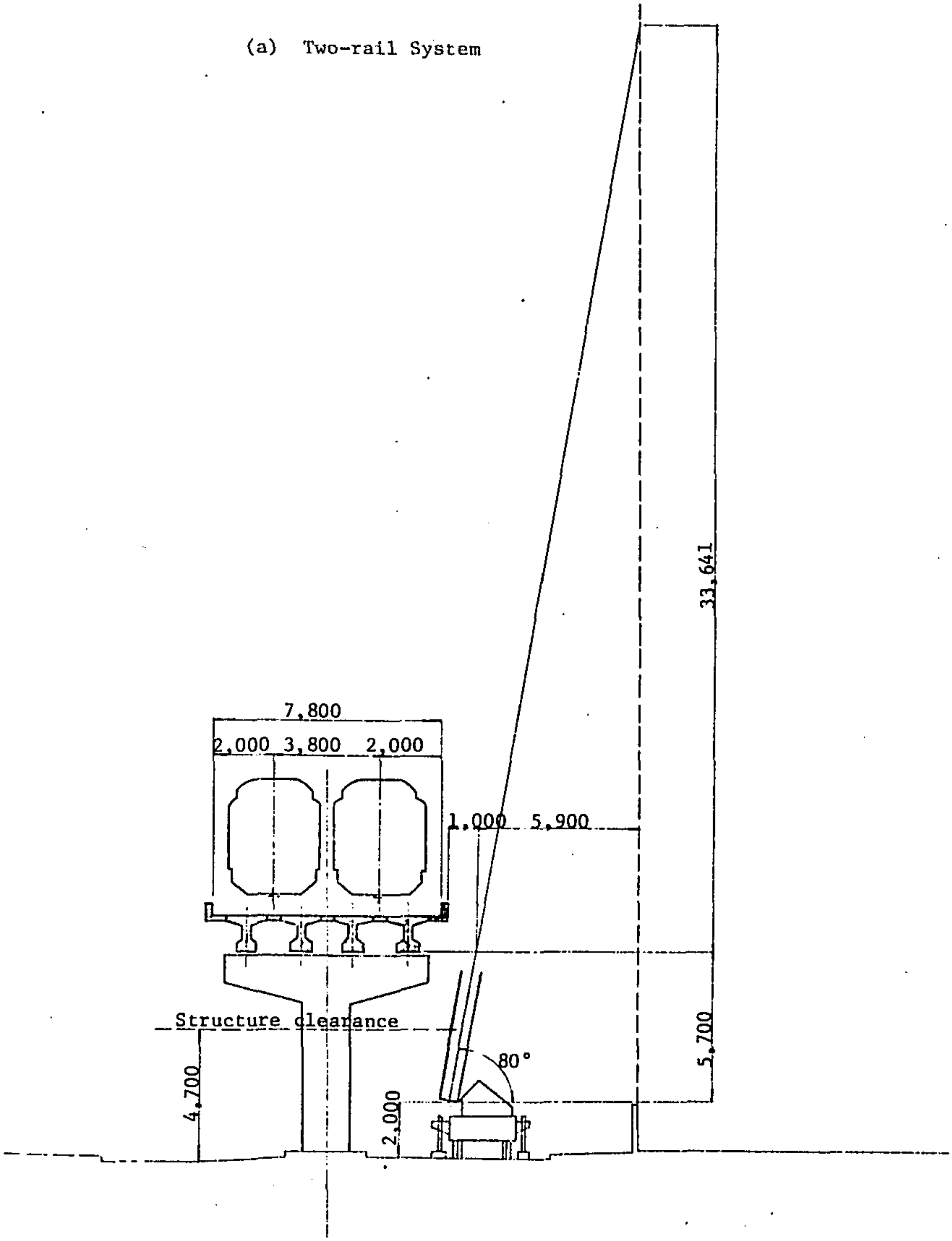
3-11-4 Lateral Allowance

Space must be provided on either side of the track, whether mono-rail or two-rail, to evacuate the passengers therein in case of a train accident or to permit rescue cars and fire engines to operate therein in case of a fire in a neighboring building. The required space is shown in Fig. 3.11.

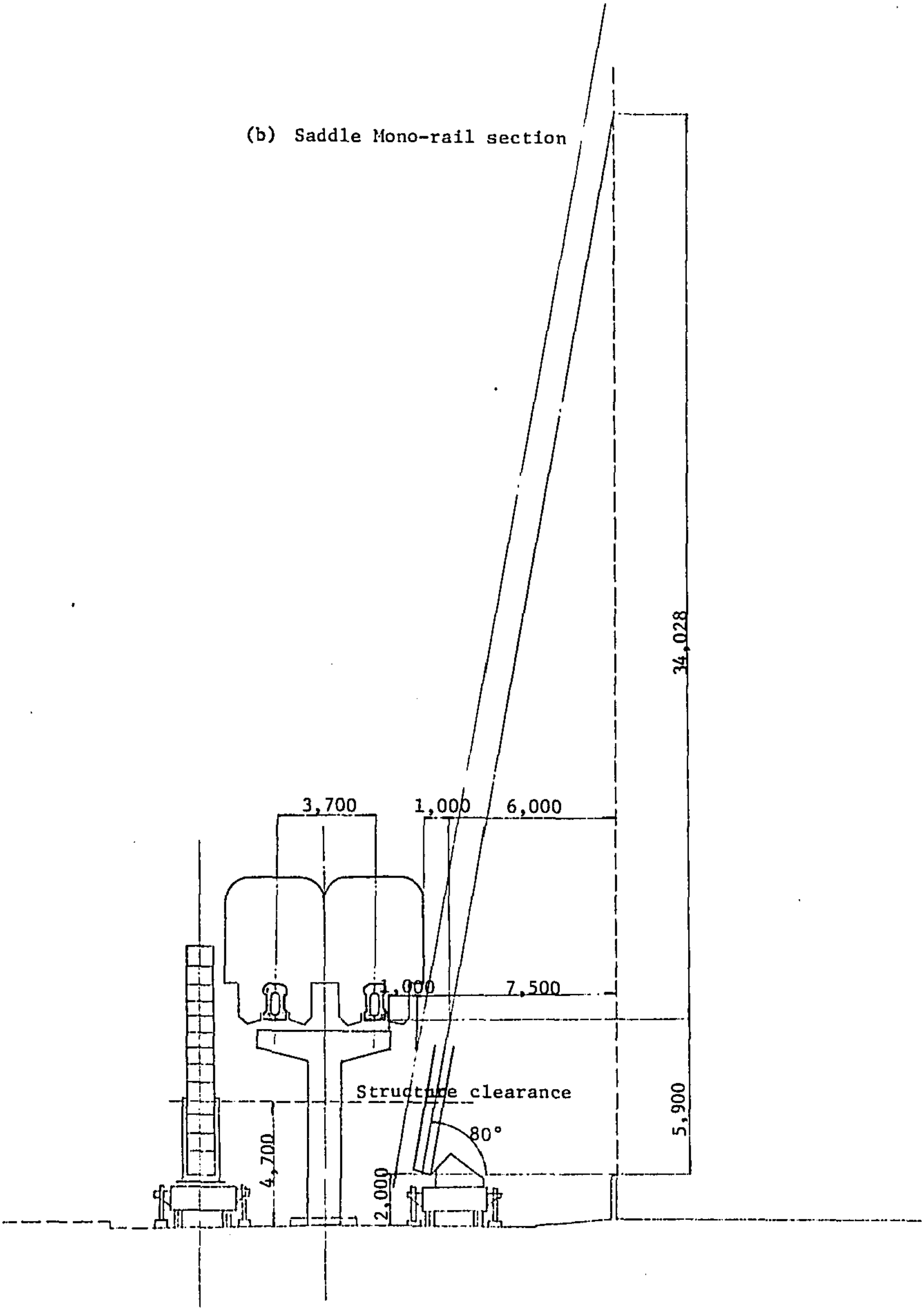
The track section of the line does not need this extra side space, but it is necessary to move existing buildings to other site to secure this space on either side of the station.

Fig. 3.11 Lateral Allowance for Fire Fighting Activities

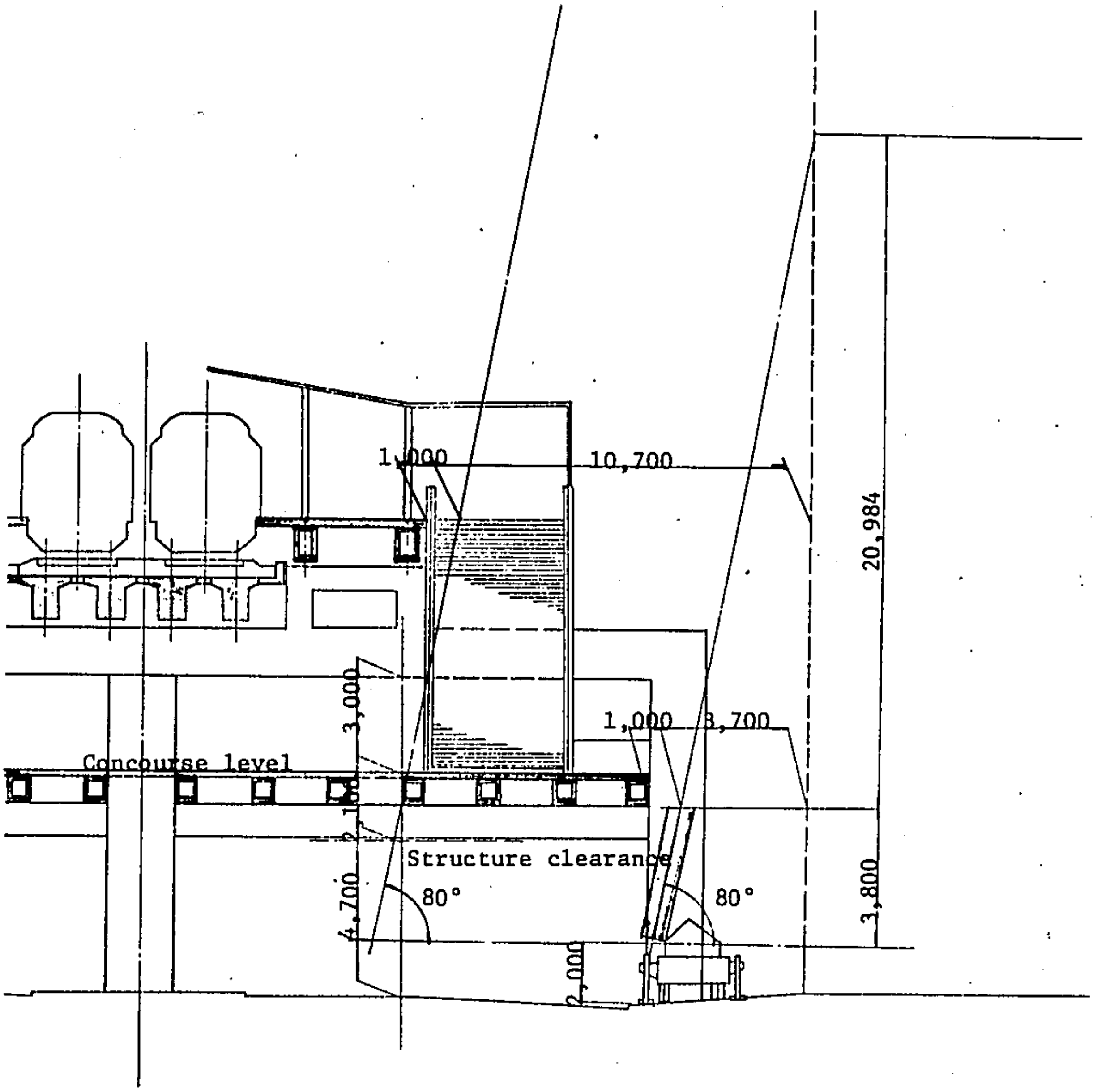
(a) Two-rail System



(b) Saddle Mono-rail section



(c) Two-rail Station Section



3-12. Environmental Assessment of the Railway Systems

It is important to compare the two-rail and monorail systems as to their influence on the environment and the life of the people living in the neighborhood of the route.

It is possible to compare the two railway systems as to each environmental factor, but the study of all environmental factors is too large a subject.

To make a detailed environmental assessment of the railway system, it is necessary to determine the importance of each environmental factor, using scores. By totaling the scores, the environmental assessment can be made complete. In point of fact, however, it is difficult to determine the order of importance for all environmental factors.

For the present, therefore, there is no alternative but to make an overall assessment according to the generally accepted concept.

The environmental factors which should be taken into account in planning the urban mass transit system include the following:

(1) Noise
(2) Vibration
(3) Natural lighting
(4) Privacy
(5) Landscape
(6) Others

3-12-1 Noise

Noise resulting from the train operation may have a number of effects on man. It may annoy him or disturb his sleep. It can interfere with his ability to converse and work, although the extent of its disturbing effect depends on the location (busy street, residential area, vacant land or congested area), time of the day (nighttime, daytime, morning or evening), and weather condition (fine, rainy or cloudy weather).

Noise, however, is a very sensational and subjective factor so that complaints about noise differ from one individual to the other.

The effects of noise on man also vary with objective conditions such as the presence of other noise source, house structure and way of life.

As it appears that Manila and its satellite cities have not passed ordinances containing noise abatement provisions, the Japanese noise regulations and typical sound levels of noise resulting from various types of railway are shown below for information.

Typical environmental standards are shown in Tables 3.16 and 3.17.

Table 3.16 Noise Control Standards in the General Areas in Japan

Area	Time			Area Disignation
	Daytime	Morning and Evening	Nighttime	
AA	45 phons or less	40 phons or less	35 phons or less	Each area is designated by the governor of the prefecture where there are noise polluted areas to which the noise control standards apply.
A	50 phons or less	45 phons or less	40 phons or less	
B	60 phons or less	55 phons or less	50 phons or less	

NOTES: 1) AA = area where sanatria and other medical institutions requiring quietness are situated.

2) A = area which is mainly residential in nature

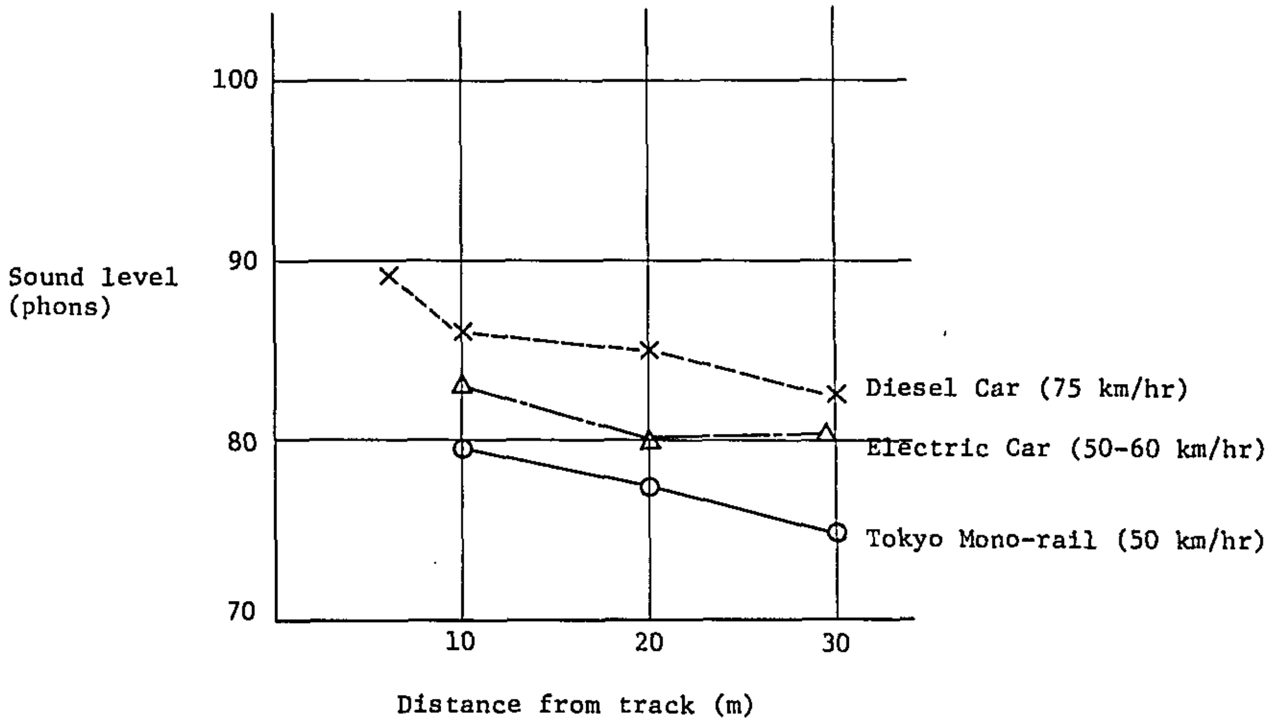
3) B = area where residences and commercial and industrial establishments are in mixed existence.

Table 3.17 Noise Control Standards in the Roadway Areas in Japan

Area	Time		
	Daytime	Morning and Evening	Nighttime
Area A which is adjacent to a roadway having two lanes	55 phons or less	50 phons or less	45 phons or less
Area A which is adjacent to a roadway having more than two lanes	60 phons or less	55 phons or less	50 phons or less
Area B which is adjacent to a roadway having two lanes or less	65 phons or less	60 phons or less	55 phons or less
Area B which is adjacent to a roadway having more than two lanes	65 phons or less	65 phons or less	60 phons or less

NOTE : The term lane means a strip of roadway land wide enough to allow a file of automobiles to pass through it safely and smoothly.

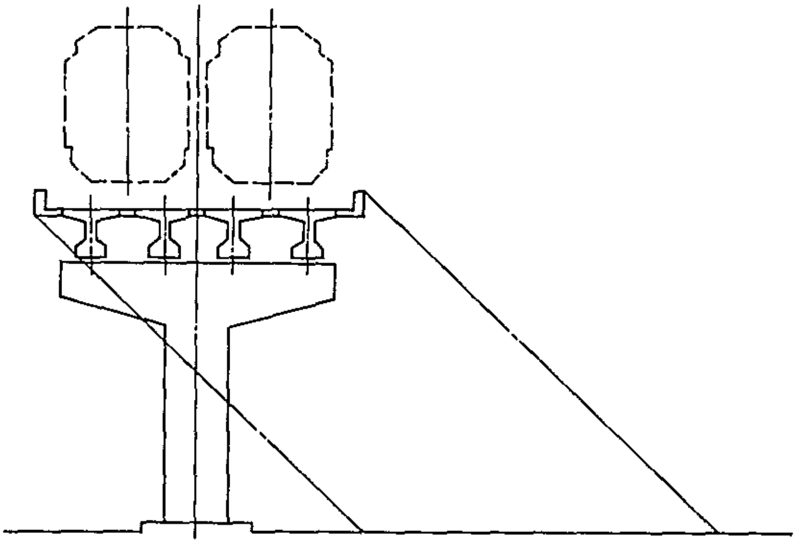
Fig. 3.12 Noise of Existing Railway and Mono-rail Lines in Japan



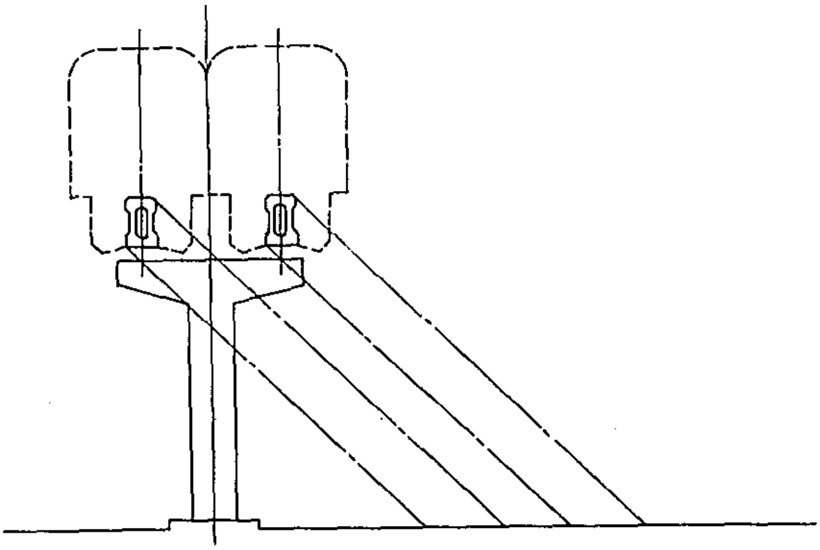
The sound level of noise resulting from various mass transit systems is about 75 to 85 phons, as shown in Fig. 3.12, and there is no remarkable difference from one system to the other, but noise resulting from the mono-rail train is slightly lower. On the other hand, the noise of the underground section is very low.

Fig. 3.13 Sketch of shading by elevated structure

(a) Two-rail System



(b) Mono-rail System



3-12-2 Vibration

In the two-rail system, the vibrations resulting from the pounding of the wheel and rail are transmitted through the track, piers (or tunnel structure) and ground to the surface buildings. The mono-rail cars which are equipped with rubber tires give less vibrations.

The vibration greatly varies with the soil conditions. Since the soil conditions differ from one site to the other, the vibration level measurements do not apply everywhere.

As vibration is a recent social problem in Japan, much information has not been accumulated in this respect.

3-12-3 Natural Lighting

The effect of the elevated railway on natural lighting is a serious concern to the people living in the neighborhood of the railway.

The mono-rail whose track rests on a file of longitudinal girders does not affect the natural lighting of wayside residences and buildings so much as the elevated two-rail track.

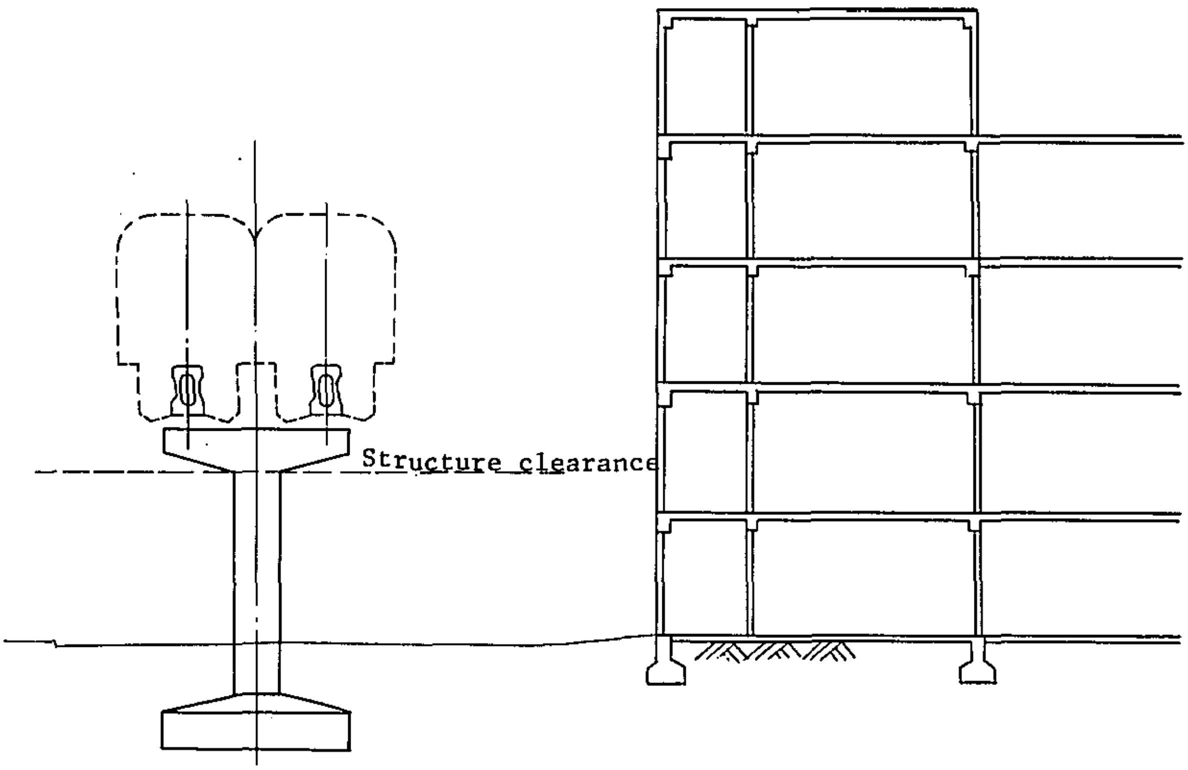
The effect of the elevated station does not differ from the mono-rail to the two-rail system, since the elevated stations of both systems are built to the same length and platform width.

3-12-4 Privacy

Many streets of Manila city including Quezon Boulevard and Taft Avenue are closely lined with residences and buildings. If an elevated railway is built along these streets, these residences and buildings are exposed to the view from the train.

This problem does not differ from the mono-rail to the two-rail system, so long as it is elevated. At present, however, there are no established regulations concerning privacy in any part of the world.

Fig. 3.14 Sketch of Sight Range from Elevated Section



3-12-5 Landscape

The concept of urban landscape has evolved from era to era, but one of the most important functions of the modern city is to respect the human rights. The urban mass transit system to be built in the modern city must, therefore, be so planned that it may harmoniously blend with the natural and cultural aspects of the modern city landscape.

The elevated structure has a great influence on the landscape, and neither of the two railway systems can completely merge into the landscape, so long as it is elevated, although the demerit may be lessened through well conceived planning.

Apart from this problem, however, it should first be decided whether the traffic condition of the city permits the new mass transit system to go underground or not. And, when dealing with the problem of landscape, it should be borne in mind that the subjective effect is considerable.

3-12-6 Other Problems

(1) Interference with Wireless Wave Reception

The interference with broadcast reception does not differ from the mono-rail to the two-rail system, so long as the elevated structure is used.

CHAPTER 4

CONCLUSION

The merits and demerits of the two-rail and mono-rail systems have been studied from a broad angle so as to suggest a better system for the project of Manila Rapid Transit Railway construction. The conclusions derived from this study will now be briefly mentioned.

(1) The two-rail system has been adopted as an urban mass transit system in the vast majority of big cities of the world.

(2) The mono-rail system requires a larger number of cars than the two-rail system. This means that the mono-rail system is economically less advantageous, because it involves a heavier investment in rolling stock and greater expenses of car maintenance and repairs, so long as the rolling stock currently in use is compared between the two railway systems.

(3) The mono-rail train made up of smaller size cars cannot transport as many passengers as does the two-rail train, but this problem can be solved by the use of a longer train formation. The situation where traffic demand during peak hours can be met by two-rail trains of 6 cars generally requires the operation of mono-rail trains of 8 cars. The train length being variable, there is nothing to choose between the two railway systems concerning traffic capacity.

(4) The comparison of two traffic systems is meaningless, if they differ in structure. In the light of the traffic condition in Manila city, the mass transit system to be built there, whether mono-rail or two-rail, seems to give a better result, if it goes underground. The main consideration in the comparison of the structure between the two systems may be the construction cost rather than the

engineering technicalities. If the elevated structure is to be adopted, mono-rail will be a little cheaper to build than two-rail. If the underground structure is to be adopted, the mono-rail system will be more expensive to construct, because the track structure and car size of the mono-rail system requires that the tunnel be built to a larger cross section.

(5) The car depot of the mono-rail system may use a loop track layout to reduce the number of turnouts, but it increases the land acquisition cost. The area of required land little differs from mono-rail to two-rail, if the turnout layout is the same for both systems. Since the mono-rail track is laid on top of girders, track maintenance is not easy, whereas the two-rail track made up of ballast, cross-ties and rail is easy to inspect and repair.

(6) The assumption is made that the transit system, whether mono-rail or two-rail, is powered by DC 750 V. Power demand is higher in the mono-rail system than in the two-rail system, although it depends on station spacings, track curvature, track grade and car performance. In the two-rail system, power to drive the train is collected from the third rail and track, whereas the mono-rail system requires to install a positive- or negative-charged rail on either side of the track.

(7) The two-rail system now uses automatic block signaling. This uses track circuits which are short-circuited by the axles of a train to energize and de-energize the relay, thus continuously controlling train operation. If the same signaling method is to be used in the mono-rail system also, it is costly. In the saddle mono-rail system, the

practice is to use a check-in/check-out block protection method which is less expensive. The railway system, whether mono-rail or two-rail, should be monitored through remote control from a control center.

(8) The operating kilemeterage, number of stations and railway structure being the same, the construction costs of the mono-rail and two-rail systems, though approximate, can be compared as follows:

(8)-(1) Construction costs for civil works

Construction costs, though approximate, are estimated as follow, whereby the distance for elevated section is 7.5 Km, and the number of stations is six station. The underground section is 17.5 Km including a shield section of 1.5 Km, and the number of station comes to 17 stations.

Unit: 1,000$

Railway System	Elevated Section	Underground Section	Total
Mono-rail system	28,300	327,100	355,400
Two-rail system	42,000	254,300	296,300

The construction costs shown above do not include rolling stock, power supply facilities, signalling, communication system, and machinary equipments.

(8)-(2) The costs of rolling stock

The number and costs of rolling stocks are estimated as follows:

Unit: 1000 $

System	Number of cars	Costs
Mono-rail	384	145,000
Two-rail	288	109,000

The number of cars has been planned for passenger volume 1,280,000 person/day to meet future traffic demands.

(8)-(3) Construcion costs of facilities

The other construction costs, such as power supply facilities, signalling, communication system and machinary equipments, not including rolling stock, and civil structure, are estimated to be approximately similar for both the mono-rail and the two-rail systems.

(9) The operating and maintenance costs of the mono-rail system are higher than those of the two-rail system, because the former requires a greater number of cars, uses rubber tyres which have to be replaced with high frequency, and consumes more power.

(10) In the mono-rail system which has no roadbed, the means to evacuate the passengers in an emergency are limited, whereas the two-rail system with a roadbed permits the passengers to escape themselves with ease. In short, the two-rail system affords a greater margin of safety. There is nothing to choose between the two systems, if they are built underground.

(11) Environmental Assessment

As common sense suggests, less noise and vibrations result from the mono-rail cars with rubber tyres than the two-rail cars with iron wheels. No conclusion can be reached as to the effect on the landscape, because the subjective effect is considerable in this regards.

The conclusion has been drawn from this study that the two-rail system should be adopted in the construction of the rapid transit railway of Manila city, because its advantage over the mono-rail system is obvious from the overwhelming prevalence of the two-rail system in major world cities, lower construction cost, greater safety of passengers, and other considerations.