REPORT ON

URBAN TRANSPORTATION SYSTEM

TEHERAN IRAN

OVERSEAS TECHNICAL COOPERATION AGENCY

GOVERNMENT OF JAPAN

[illegible] 1970

PREFACE

The Government of Japan, in response to the request of the Government of Iran, entrusted the Overseas Technical Cooperation Agency with the study on a transportation system in Teheran.

The Agency, appreciating the necessity of establishing a comprehensive plan for transport facilities to satisfy the rapidly increasing transportation desires in the City of Teheran in the future, despatched a survey mission headed by Mr. Shozo Tanifuji; Ex-Vice Minister of Hokkaido Development Agency, consisting of specialists respectively in city planning, urban transportation, road planning, underground railway and monorail planning and road traffic engineering. The mission conducted a thorough investigation of the transport conditions in the City of Teheran over a period of about forty days in August and September 1969 in close cooperation with the Government of Iran and the City of Teheran. The findings of the investigation are compiled in this report.

It will be the greatest pleasure to me if the present survey will serve to promote the development of the City of Teheran and the friendly relations between Iran and Japan.

I wish to express my sincere gratitude all the Iranian parties concerned and the ambassador and his staff of the Japanese Embassy at Teheran, who were so generous to render zealous assistance and cooperation to the mission in carrying out its field investigation.

April, 1970

Keiichi Tatsuke
Director General
Overseas Technical Cooperation Agency

Report on Urban Transportation System

Teheran, Iran

INTRODUCTION

Objective and Scope of the Survey

The City of Teheran, the capital of Iran, is one of the cities which deserve very clearly to be called "exploding cities", presenting the world-wide tendency of a bursting increase in the urban population and the spreading of metropolitan area.

The most conspicuous symptom developed in these rapidly growing cities is the traffic paralysis. Such traffic paralysis is caused by the activities of modern cities with their complicated and highly advanced functions supported by the transport facilities remaining unimproved. There is already a traffic stagnation appearing chronically in the city area of Teheran. Such traffic stagnation will be aggravated with the development of the city in the future. Unless proper measures are taken at an early date, it will become difficult even to maintain the life of the city, to say nothing of its healthy growth.

The objective of the Japanese survey mission was to establish a comprehensive plan of transport facilities needed for the development of the City of Teheran.

(a) Land Use Plan

Any plan of transport facilities in a city must be drawn up based on an adequate land use plan in order to secure the smooth flow of the urban traffic which may be regarded as an urban activity itself.

The City of Teheran has the city plan of "linear pattern" already prepared to develop the city in the direction from east to west. A plan of transport facilities based on the land use plan arranged on the said pattern is set forth in Part I of this report. On the other hand, the above city plan is to be compared with that of "combination of ladder and circular pattern" which is adopted by almost all of the great cities in the world.

The active discharge of various functions of a city can be attained by the well arranged land uses and the transport facilities linking them effectively with each other. Based on this thinking the Japanese survey mission has drawn up a city plan which is described in Part II of the report.

(b) Planning of Urban Expressway and Means of Mass Transportation

Any transport facilities other than the proposed urban expressway means of mass transportation will no longer be able to meet the increasing demands for transportation due to the widening of the urban area and the vigorous performance of the urban activities. From this viewpoint several route plans are proposed in this report for urban expressway, railway and monorail, with the construction costs and priority studied for each of the plans. Plans for transport facilities drawn up on the basis of "linear pattern city planning" and "combination of leader and circular city planning" are described in Part I and Part II, respectively.

(c) Required Urgent Improvement of Road Traffic

The urgent measure proposed to be taken for streets is intended to improve, even a little, the prevailing traffic stagnation by increasing the traffic capacities of the existing streets by effective traffic engineering measures. It is a traffic measure which can be implemented easily, apart from the establishment of a permanent transport measure for providing urban expressways and means of mass transportation, etc.

This proposal includs a grade separation of Ave. Shah-Reza and the systematization of signals of major streets and the areal control in the central area of Teheran.

To draw up these plans, the mission stayed in City of Teheran for a period of 40 days from August 23 to September 30, 1969 and engaged in field surveys and discussions with the Iranian Government Authorities and the Municipality of Teheran.

Plan for transport facilities of Teheran presented herein has been mapped out from the results of these field surveys and discussions.

Formation of the Mission

The formation of the Mission is as follows:

TANIFUJI, Shozo	(Chief of the Mission) Ex-Vice-Minister, Hokkaido Development Agency, Office of the Prime Minister
MIMINO, Shin	(Assistant Chief of the Mission) Director, New-Line Construction Office, Teito Rapid Transit Authority
WATANABE, Yoshiro	(City Planning) Director, City Planning Division, Sizuoka Prefecture
HASEGAWA, Yoshiaki	(City Planning) Deputy Coordinator, First Planning Department, National Capital Region Development Commission, Office of the Prime Minister
ABE, Mitsuo	(Urban Transportation Planning) Assistant Policy Planning Officer, Minister's Secretariat, Ministry of Transportation
IWAI, Hikoji	(Road Planning) Deputy Head, Road Administration Division, Road Bureau, Ministry of Construction
TOMIHARI, Seiichiro	(Rapid Transit Planning) Chief, Design Section, Construction Division, Teito Rapid Transit Authority
SHITO, Yoshitomo	(Rolling Stocks and Electric Facility) Deputy Chief, Facility Section, National Railway Division, Rialway Supervision Bureau, Ministry of Transportation
AWANO, Hiroshi	(Monorail Planning) Engineer, Engineering Department, Tonichi Kohtsu Consultant Co.
MURAKAMI, Yorio	(Traffic Engineering) Assistant Chief, Planning Section, Planning Division, Tokyo Expressway Public Corporation
TOKUMARU, Masaya	(Coordination) Engineer, Development Survey Division, Overseas Technical Cooperation Agency

ACKNOWLEDGEMENT

It would not have been possible to complete the survey and planning on Teheran Transportation System so satisfactorily without the close cooperation of the Traffic Engineering Department, Teheran Municipality. The Mission expresses its profound gratitude to Hon Hasan Zahedi, Minister of Interior, Imperial Government of Iran and Hon. Javad Shahrestani, former Major of Teheran.

Special mention must be made of the exceptional assistance given by Dr. Nasser Sabet, Head of Traffic Engineering Department, Eng. Faramand Cohan, Mr. Mehdi Razavi, Mr. Mohamed Hossein Givechian and other members of the said Department.

The Mission also wishes to extend its thanks to Hon. Hossein Farhadi, Chairman, Hon. Abolghasem Taffazoli, Deputy Chairman and other members of the City Council and many prominent officials of Ministries of Iranian Government and Municipality of Teheran whose names are given below.

Teheran Municipality

Mr. Abdol Hossein Ebrahimi	Deputy Mayor of Teheran
Mr. Nehrab Barzegar	" " "
Mr. Karim Gudarzi	" " "
Mr. Hushang Samii	" " "
Dr. Ardekanian	Head of Design and Research Department
Eng. Hariri	" " Engineering Office
Eng. Ehte Shami	" " Development Department
Eng. Korloo	" " City Planning Department
Mr. Honami	" " Flood Control Department
Mr. Hosain Sigari	" " Asphalt Division

Ministries of Iran

Hon. Vassigh	Vice-Minister, Ministry of Road
Hon. Badie	Vice-Minister, Ministry of Housing and Development
Dr. N.Djalinousse	Head, Railway Department, Ministry of Road
Mr. Shalchian	Head, Planning and Programming Department, Ministry of Road
Mr. Famour Zadeh	Head, Traffic Department, Ministry of Road
Mr. Basseri	Head, Transportation and Communication Department, Plan Organization
Mr. Rais Zadeh	Head, Static Bureau, Plan Organization
Mr. Balmacky	High Council for City Planning

Finally, acknowledgement must be made also to Mr. Moaveni, Project Manager, Farman Farmaian Engineering Consultants Co., who helped the mission in the survey and planning.

PART I TEHERAN TRANSPORTATION SYSTEM

(PROPOSAL WITH LINEAR PATTERN CITY PLANNING)

CONTENTS

CHAPTER 1 SUMMARY OF FINDINGS AND RECOMMENDATIONS

1.1 Fundamental Principles for Planning Teheran Transportation System

1.1.1 Given Preposition for Teheran Transportation System Planning

Future framework of Teheran on which transportation system has been worked out is as follows.

a) Teheran shall be populated five and a half million in 1991.

b) Future urban area shall be 600 Km^2 and its boundary is shown on the map. (Fig. 2-2-1)

c) The urban area is divided into 10 zones and each zone will be populated approximately 500, 000 persons.

d) Each of 10 zones forms sub centers and the location of them are shown on the map. (Fig. 2-2-1).

The given prepositions are expecting to develop Teheran in a linear pattern from east to west.

1.1.2 Fundamental Principles for Traffic System Planning

a) Establishment of expressway and rapid transit network connecting present city center and new subcenters.

b) In working out new traffic network, considerations must be paid for establishment of commodity circulation centers which are now scattered in the city and generating heavy traffic. And further, for the services to new administrative center proposed in Abbas-Abad, Olympic stadium under construction in west and new international airport which will be proposed in south.

c) The comprehensive traffic network must take into consideration the modal split between rapid transit, urban expressways and streets, corresponding to the future traffic demands under the given preposition of 5, 500, 000 populations in Teheran.

It is expected that number of persons comming into the city center of Teheran reaches at 660, 000 per hour in a peak hour, and by only passenger cars, it needs 380 lanes, i. e., 80 roads of 5 lanes on each direction that seems very hard to realize. By bus it also needs 70 lanes, i. e., 35 exclusive bus routes of 2 lane each. The urban rapid transit have a capacity of upto 40, 000 person/ hour, at the normal rated capacity, only by one line. So, in such a city as Teheran where the movement of the people are in a few directions, east - west and Tajrish - city center, rapid transit is really effective.

Number of persons coming into the center in a peak hour are roughly estimated that approximately 230, 000 persons will avail urban rapid transit and 430, 000 persons will avail buses and other cars.

d) Origin and Destination Survey should be executed in Teheran. O.D.

survey provides basic data for traffic system planning and the traffic facility plans. And proposed projects in this report should be reviewed basing on the study of the result of the O.D. survey.

1.2 Expressway Network

1.2.1 Basic Considerations

Street network in Teheran has been already developed to a considerable level, yet construction of urban expressways which enable rapid and mass vehicular traffic flow is the most effective tools to meet the expansion of traffic demands brought by development of motorization.

We have prepared a plan of urban expressway network in Teheran Metropolitan Area with enough consideration.

a) The expressways should be feasible from the stand points of not only technical but also economical and social aspects.

b) The expressway network should be adequately corresponding to the future growth of traffic demands.

c) Planning for the future cannot ignore present problems. Construction of expressways should provide a relief to over-crowded traffic facilities, even when a section of an expressway is opened to the public.

d) Expressway in built-up areas should be designed with careful consideration for preservation of fine urban view such as road-side trees and historical monuments and etc.

1.2.2 Network Plan

The desirable pattern of urban expressway network is believed to be the "Ring and Radial Pattern" for the existing urban area of Teheran and the "Grid Pattern" for the future development area in the western part. So we have applied a systematic combination of both patterns.

At least two ring expressways should be provided for the existing built-up area of Teheran. They are the ring expressway surrounding Central Business District (C.B.D. Ring Expressway) and the Suburban Ring Expressway surrounding the outer fringe of the built-up area.

a) C.B.D. Ring Expressway

C.B.D. Ring Expressway should be located as close as possible to C.B.D. to assure easy access to C.B.D. and to enable to absorb the huge amounts of traffic demands generated there.

C.B.D. Ring Expressway is scheduled to be one-way operated with three lanes of elevated structures on the existing streets. Adoptation of one-way system will bring a comparatively narrow width of the expressway and simplified interchanges.

Thus removal of buildings and acquisition of right-of-way in built-up area will be minimized. Social conflict will be prevented and construction cost will be economical.

Several super-block buildings equipped with large parking spaces, bus terminals,should be scheduled using, for instance, the left over sites of government buildings and other deteriorated buildings. Branches from C.B.D. Ring Expressway will be extended to these buildings in order to improve accessibility to C.B.D.

C.B.D. Ring Expressway is scheduled to be located on following streets. Boulvard, Ave. Siroos, Ave. Molavi and Ave. Simetri, yet there leaves room for consideration of using Ave. Takhte Jamshid. It should be decided with enough consideration from the point of easiness of acquisition of right-of-way, preservation of scenic beauty and accessibility to C.B.D.

C.B.D. Ring Expressway will be connected to Suburban Ring Expressway by several four-lane Radial Expressways.

b) Suburban Ring Expressway

Suburban Ring Expressway is generally located along the outer fringe of built-up area and connects the radial inter-city highways around Teheran.

Suburban Ring Expressway will be effective for improvement of urban traffic condition providing possibility of relocation of commodity circulation facilities which are scattered in the city at present.

c) Western Suburban Expressways

Western suburb of Teheran is expected to be developed in ladder pattern connecting several zones, each having half a million of population.

Two new expressways are planned, one passing through the residential area in the northern part of the existing Teheran - Karaj Super Highway and the other through the industrial area along the national railway south of the Super Highway. These expressways should be connected each other by some north-south expressways to compose a grid pattern.

The Northern Expressway should be extended to Tajrish and Chiraz to serve the residential area in the northern part of Teheran.

1.2.3 Priority in the Start of Work

The proposed urban expressway network, about 200 km in its total extension, is estimated to incur a construction cost of approximately 50 billion Rials.

In view of the anticipated growth of motorization, this investment is in a impending necessity and the benefits derivable therefrom far surpass the initial investment.

However, since it is impossible to construct all the above mentioned routes within a short period, priority should be given to C.B.D. Ring Expressway and the Radial Expressway No.1 which connects the C.B.D. Ring Expressway with Teheran-Karaj Super Highway and Ave. Kennedy.

1.3 Rapid Transit System

1.3.1 Necessity of Rapid Transit System

Rapid Transit System in the large cities of several million population in the world plays an important role in the urban transportation.

The advantages of urban rapid transit are safety, punctuality and mass-transportation which could not be expected by any other traffic facilities so much. The urban rapid transit, subway for example, have a capacity of mass-transportation upto 40,000 persons/hour, at the normal rated capacity, only by one line. In such a city as Teheran where the movement of the people are in a few directions, east - west and Tajrish - city center, rapid transit is really effective.

As the type of rapid transit system both subway system and monorail system are conceivable. It goes without saying that the decision as to which type is to be selected must be made after a careful study has been made on the transport requirement and the characteristics and capabilities of each system, as well as an economical study with the consideration given to the total investment (land, structures, rolling-stock, car-sheds, maintenance shop and electrical equipment). Though the monorail system is also conceivable for Routes Nos. 1 and 2 from a point of its capacity for the estimated number of passengers, as for Route No. 1, adoption of subway system is recommended in view of the adaptability of subway system to the growing activity of the Metropolis and future innovation in the transportation and also on the ground that the system which enables through operation with the State Railway is more advantageous to the Metropolis. For Routes Nos. 3 and 4, the subway will be most suitable in view of the future increase in the traffic volume.

In order to minimize the construction cost, subway lines shall run under ground in the built-up city area, and be elevated in suburbs, but even in the city area it should be elevated as much as possible.

Though the underground structure of monorail is also conceivable, such project inevitably increases construction cost tremendously and one of the merits of monorail is that it can be built as elevated structures. As the monorail is built over the existing streets in most cases, adoption of this system is considered very advantageous with respect to both construction cost and construction period if such elevated structures are permissible in view of the future city structure and the beauty of the city. Therefore, this system should be given due consideration.

1.3.2 Network Plan

The points to be considered for planning of City Rapid Transit System.

a) Track routes should pass through the city center.

b) Train operation shall be simplified as much as possible; one operation for one track route is the best.

c) For selection of the route, place and space for carsheds and workshops should be also be taken into consideration.

d) Iranian State Railway lines, especially in the suburbs of Teheran, must be improved and electrified, as a part of the city rapid transit route.

Following the fundamental principles mentioned above, proposed rapid transit network is as follows:

(1) Route No. 1 passes through Abbas-Abad and goes to Tajrish, Evin and upto Mekanir in the north, and is to be connected with State Railway at Central Station so that it is operated through State Railway.

(2) Route No. 2. As shown in many large cities in the world, the vehicular traffic on the highway connecting city center and airport will cause very bad congestion all the time. So rapid transit will be really indispensable on this line as the most safe, accurate and mass transportation system.

Route No. 2 which starts from Teheran-Pars stops at business center and airport, then comes to new junction station where it connects with State Railway.

For new airport, this route 2 could be e xtended further more or otherwise State Railway shall be prolonged.

(3) The route Nos. 3 and 4 will be having the transportation demands in future as the main line. These route 3 and 4 come to Daryan-e-Now together and separated there; route 3 goes through the present business center to the future sub-center at Soleymaniyeh, meantime route 4 goes through new administrative center in Abbas-Abad upto Teheran-Pars.

(4) Improvement of the present Iranian State Railway and make use of it as a part of city rapid transit route. In other words, State Railway between Teheran and Karaj is to be improved immediately and to be used as the trunk line in the Teheran Metropolitan Area which will be expanded towards the west. And another one between Teheran and Shah-e-Rey also shall be prepared for increase of transportation demands.

The four recommended routes has a total length of 112.1 km, with the following breakdown:

Route No. 1	19.5 km
" " 2	23.2
" " 3	32.3
" " 4	37.1

As stated in Chapter 4, 6-11 of this volume, the total investment will amount to 42, 960 million Rials if the subway system is to be adopted for all the four routes. This amount, however, is required only for the final stage when trains are operated at intervals of 2.1/2 to 3 minutes with a train formation of 6 to 8 cars. For the initial stage of operation when the trains are operated at intervals of five minutes, the number of cars required may be reduced to a half of that required for the final stage.

Concerning the priority of construction, which will be further discussed in Chapter 4, 6-10 of this volume, construction of the section of Route No. 1 between the Central Station and Abbas-Abad with a total length of 11.5 km is recommended as the first stage of the project.

The estimate of initial investment mentioned previously is for the event that the subway system has been adopted for all the four routes. A comparative design of Route 1 and Route 2 for the event that the monorail has been adopted for the two routes is shown in Chapter 4-7 for additional information.

1.3.3 Improvement of State Railway

a) Diesel cars (not locomotive but passenger cars with an individual diesel engine equipped in each car) of good performance is to be used, and modernization of signal shall be considered for high speed operation.

b) Complying with the increase of passengers and freights, rail line should be double-tracked and electrified.

c) Then, passenger and freight lines should be completely separated and elevated, which are really necessary for high-efficient and safe operation.

At the final stage of such improvements, State Railway is to be junctioned with city rapid transit and operated through each other so that the passenger could come down directly to the business center without changing the train. This is one of the most useful and practical ways.

This way of improvement is also economical and practical, because it would increase the capacity of such traffic facilities in several steps, but not in one time. For example the diesel cars which are used at an early stages, can be transferred to non-electrified part after electrification is achieved.

According to the above idea, 100 - 200 Km of State Railway around Teheran should be improved, and the first priority should be given to the improvement of the lines between Shah-e-Rey, Teheran and Qazvin.

1.4 Required Urgent Improvements of Road Traffic

To ease the present congestion of vehicular traffic on major streets in Teheran, the powerful measure is to increase the traffic capacity of major intersections.

The following steps shall be taken in principle to improve the traffic capacity of the intersections:

a) Enforcement of proper traffic regulations including prohibition of left-turn and straight crossing the major streets from small streets, and positive adoption of one-way traffic operation.

b) Improvement of intersections by applying effective means of traffic engineering such as proper geometric design of intersections including provision of traffic islands, adoption of optimum signal control, for instance, progressive signal system to be provided along main streets, and further, area signal control system to be operated by electronic computer in the central business district.

c) Grade separations to be constructed at congested intersections of the major streets as Ave. Shahreza.

Abovementioned improvements are actually designed at Ave. Shahreza's intersections, and those are disclosed in Chapter 5.

According to the statistic of traffic accidents in Teheran furnished by Police Department, vehicles to pedestrian accidents are over 8% of the total accidents occurred in 1968. Protection of pedestrian from traffic accidents should be strongly taken into consideration by adoption of optimum pedestrian signal, construction of grade separated pedestrian tunnels or bridges for crossing major streets, and regulation for pedestrians crossing the carrageway only at zebra zones at intersections.

Bus service is the main public transportation facilities in Teheran, however, those concentrations in the central business district make traffic congestion worse, so the service routes should be in loop. We would like to propose also construction of a multi-purpose traffic building connected directly to C.B.D. Ring Expressway, of which, for example, ground floor is for bus-terminal and the other floors for off-street parking, in the city center.

CHAPTER 2 CITY PLANNING

2.1 Present State of Teheran

2.1.1 Topography

Iran is bordered on the east by Afghanistan and Pakistan and on the north by the Soviet Russia and the Caspian Sea. On the west by Turkey and Iraq and on the south by the Persian Gulf.

Iran has a total land area of 1,648,000 km^2, the majority of which are dry land and the rest is also under severe climate conditions. Teheran is the capital of Iran and is situated at the point (longitude 52°E, latitude 36°N), approximately 200 km south of the Caspian Sea: which lies in the north of Iran.

The present city area of Teheran extends 20 km from south to north and 15 km from east to west and is cut off on the north and east by the Elburz mountain range.

The city of Teheran is on the highlands more than 1,000 m above sea level and there is a wide difference in altitude even in the same city area. Elevation of the area around the Central Station of the State Railways in the south is about 1,100 m which compares with about 1,600 m at Tajrish in the north, a difference of 500 m in altitude within a horizontal distance of 16 to 17 km. The slope becomes much steeper in the north.

Accordingly, there is a difference of 4 to 5 degrees C. in the temperature between the north and south of the city.

During a period from 1943 to 1965, the maximum mean temperature recorded in Teheran was 30.4°C and the minimum mean temperature was -1.7°C with the average being 16.5°C. Average annual precipitation is 202 mm and the number of days of rainfall during a year (365 days) is 35, with the remaining 90% being fine days.

2.1.2 Population

Table 2-1-1 Population of Iran

Region	Sex	1956	1966
Total country	Male		12,981,665
	Female		12,097,258
	Total	18,954,704	25,078,923
Urban	Male		5,096,654
	Female		4,697,592
	Total		9,794,246
Rural	Male		7,885,011
	Female		7,399,666
	Total		15,284,677

As shown in Table 2-1-1, the population of Iran increased to 25,078,923 in 1966 from 18,954,704 in 1956, an increase of 6.12 million in 10 years. The average annual growth rate is about 3%, an extremely high growth rate. Accordingly, the density of population also increased from 11.5 to 15.4 persons/km^2.

As the world-wide urbanization trends, the population of Teheran Metropolitan Area increased to 9.8 million or 38.7% of the total population in 1966 from 5.95 million (31.4% of the total population) in 1955.

The population of Teheran in 1861 was merely 120,000 and that in 1934, 70 years later, was still 360,000. Since then, however, the population began to show a rapid increase and it reached 880,000 in 1946, 1,208,200 in 1956 and 2,719,720 in 1966, almost doubling every 10 years.

Such a rapid increase of population is attributed to a high social in-increase as well as natural increase. The average annual growth rate for a period from 1956 to 1964 was 5.6%, of which 2.6% was due to natural increase and the remaining 3.0% was social increase.

A study on the population in each of the 10 districts in Teheran covered by the National Census shows, as seen in Table 2-1-2 and Fig. 2-1-1, that the

Table 2-1-2 Population in each census district of Teheran

Census districts	Year	
	1956	1966
District 1		303,697
" 2		159,552
" 3		361,580
" 4		366,039
" 5		320,860
" 6		250,655
" 7		312,818
" 8		237,778
" 9		116,191
" 10		257,960
Total in Teheran	1,512,082	2,710,720
Tajrish	26,525	157,486
Rey	22,327	102,825
Karaj	14,526	44,243
Total	1,575,460	3,024,274

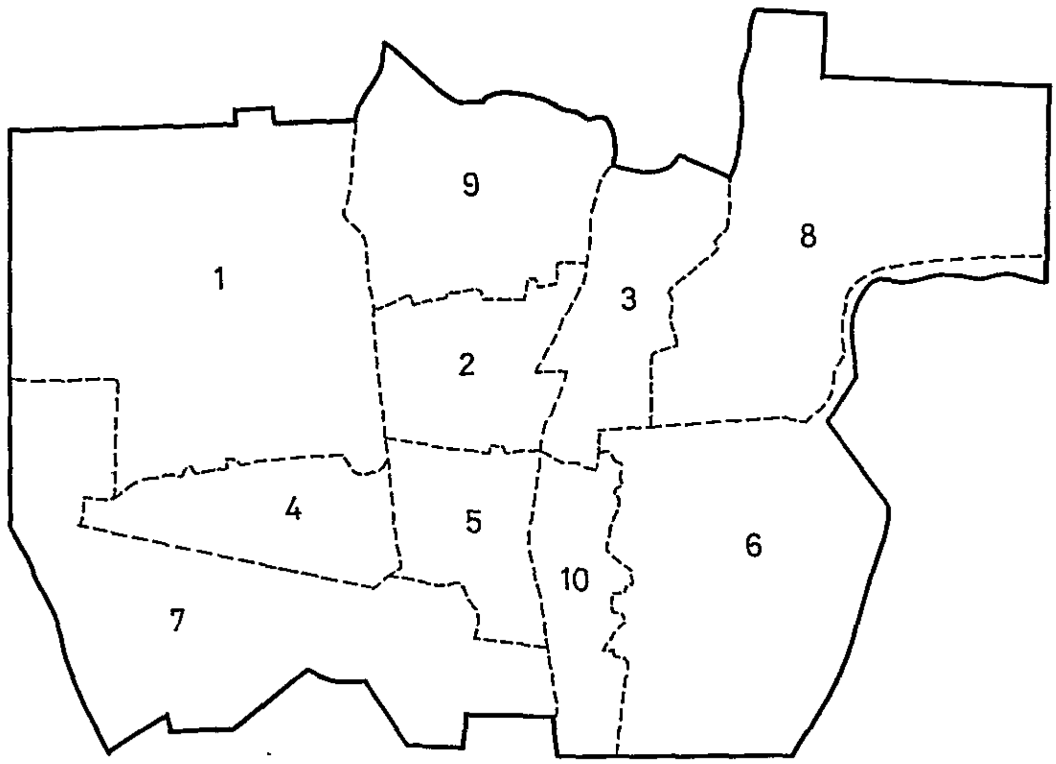


Fig. 2-1-1 Teheran census districts

population concentrates on Districts 2 and 5, both of which form the present downtown of Teheran and the density of population in these districts exceeds 200 persons/ha. Incidentally, the average density of population in all districts is 95 persons/ha.

Next, on the population in Teheran Metropolitan Area including Tajrish of the north and Karaj of the west, the population doubled in 1965 to 3,024,274 from 1,575,460 in 1956. The highest growth rate was seen in Tajrish where the population grew from 26,525 to 157,486, the increase by about six times. In Rey it grew from 22,327 to 102,825, the increase by about five times and in Karaj it grew by three times from 14,526 to 44,243.

By sex, man in Teheran in 1966 numbered 1,425,696 compared to woman totaling 1,294,124 as shown in Table 2-1-3. By age, the population of low age groups has majority with the average being 18 years old.

FIG 2 - 1 - 2 PRESENT LAND USE MAP of TEHERAN

Table 2-1-3 Population of Teheran

Age \ Sex	Male 1966	Male 1956	Female 1966	Female 1956	Both sexes 1966	Both sexes 1956
Less than 5 years	204,167	108,495	197,181	105,316	401,348	213,811
5 to 9 years	197,037	98,033	190,138	95,507	387,175	193,540
10 to 14 "	169,540	79,490	157,664	72,998	324,204	152,488
15 to 19 "	141,572	74,552	134,584	67,100	276,156	141,652
20 to 24 "	133,509	89,437	119,448	74,017	252,957	163,454
25 to 29 "	114,613	141,855	99,213	112,825	213,826	254,680
30 to 34 "	107,602		85,217		192,869	
35 to 39 "	89,850	92,120	73,492	69,456	163,342	161,576
40 to 44 "	76,760		56,351		133,111	
45 to 49 "	55,979	59,397	40,747	58,625	96,726	118,922
50 to 54 "	39,345		42,933		82,278	
55 to 59 "	23,247	35,125	24,254	33,716	47,601	62,841
60 to 64 "	31,616		32,226		63,842	
65 years and over	40,769	20,856	40,526	23,162	81,295	44,018
Total	1,425,606	799,360	1,294,124	712,722	2,719,730	1,512,082

2.1.3 Industry and Employed Population

Iran's G.D.P. (Gross Domestic Products) had grown at an average growth rate of 6.8% since 1959 and reached 441.4 billion Rls. (price in 1959) in 1966. Accordingly, G.D.P. per capita also increased at an average annual rate of 4.2% as shown in Table 2-1-4 and reached 17,856 Rls. in 1966. Breakdown of this growth rate by three industrial classifications shows that the primary

Table 2-1-4 Growth of Output and Income per Capita of Population

	Gross Domestic Product (Billion Rials)		G.D.P. per Capita (Rials)	
1959	278.2 B.R.	- %	13,391 Rls.	- %
1960	296.3 "	6.5	13,912 "	3.9
1961	311.9 "	5.3	14,289 "	2.9
1962	328.5 "	5.3	16,682 "	2.7
1963	351.4 "	9.0	15,325 "	4.4
1964	361.4 "	2.8	15,375 "	0.3
1965	407.0 "	12.6	16,893 "	9.9
1966	441.4 "	8.4	17,856 "	5.9

industry showed an average annual growth rate of mere 3%, with its share in the total industry declining annually from 31.4% in 1959 to 24.1% in 1966. In contrast with this, the secondary industry showed such a high average annual growth rate as 12.8% and its ratio to the total industry jumped to 41.3% in 1966 from 30.0% in 1959. The tertiary industry grew by 6.9% almost equivalent to the growth rate of total G.D.P., with its share in the total industry remaining on the same level.

Gross domestic investments almost doubled from 48.1 billion Rls. in 1959 to 93.9 billion Rls. in 1966 and its share in G.D.P. also increased from 16.2% to 19.9%. By breakdown, the share of investment in the construction of dwellings is particularly high (Table 2-1-5).

Table 2-1-5 Gross Domestic Investments in billion Rials (1959 price)

Items \ Year	1959	1960	1961	1962	1963	1964	1965	Average
1. Agriculture	2.62	2.67	2.52	1.79	1.94	3.32	2.95	
% of G.D.I.	5.5	4.9	4.5	3.9	3.7	5.2	3.7	4.5
2. Transportation	13.85	12.92	11.27	8.63	11.22	15.14	19.29	
% of G.D.I.	28.8	23.7	20.2	18/8	21.2	23.8	33.9	23.0
3. Service	2.27	3.31	3.83	4.41	3.21	2.81	3.51	
% of G.D.I.	4.7	6.1	6.9	9.6	6.1	4.4	4.3	5.8
4. Dwellings	18.27	23.57	28.12	25.52	31.37	35.89	42.55	
% of G.D.I.	38.0	43.3	50.4	55.8	59.2	56.3	52.6	51.1
5. Industry	11.07	11.94	10.03	5.43	5.21	6.54	12.53	
% of G.D.I.	23.0	20.0	18.0	11.9	9.8	10.3	15.5	15.6
Total G.D.I.	48.09	54.41	55.77	45.78	52.95	63.70	80.83	

In the city of Teheran, the center of politics as the capital of the nation as well as the center of economy, the G.D.P. amounting to 135 billion Rls. or 1/3 of the total G.D.P. is concentrated, and 60% of the total investments is carried out in Teheran.

Employment structure by industry shows that the majority of workers are employed by the tertiary industry, which vividly illustrates the character of Teheran as the center of politics, economy and culture. Of the total employed population of 755,000 in 1966, those employed in the primary industry accounted for only 1.6% compared to 63.6% for the tertiary industry and 35.3 % for the secondary industry. Breakdown of employed population by industry shows, as seen in Table 2-1-6, that the service industry has the largest share, accounting for 32.2% of the total employed population, followed by manufacturing, commerce, construction, transport and communication industries in that order. A large number of employments in the service industry is due to the fact that in Teheran, as the capital of the nation, various government functions, embassies and legations of many countries are concentrated in this city or many establishments such as hotels and restaurants are located. Against this, a relatively small employed population in manufacturing is probably due to the result of the government measures imposing restrictions on the establishment of factories in Teheran to

Table 2-1-6 Employed Population by Major Industry Group in Teheran, 1966

	Total		Male		Female	
	Number	Ratio	Number	Ratio	Number	Ratio
Agric., forestry, hunt and fish	7,903	1.5	7,670	1.1	233	0.3
Mining and quarrying	440	0.1	406	0.1	34	0.0
Manufacturing	198,952	26.2	188,335	27.8	10,617	13.7
Construction	67,324	8.9	66,884	9.9	440	0.6
Elec., gas, water and san. serv.	16,783	2.2	16,378	2.4	405	0.5
Commerce	137,399	18.1	133,741	19.7	3,658	4.8
Transport, stor. and commun.	59,284	7.8	57,855	8.5	1,429	1.9
Services	244,399	32.2	186,400	27.5	57,999	75.4
Activities n.a.d.	22,690	3.0	20,513	3.0	2,177	2.8
Total	755,174	100.0	678,182	100.0	76,992	100.0

prevent the concentration of population. Meanwhile, employment in construction industry accounts for about 9% of the total employed population, and such construction projects as urban renewal, housing project, and road construction are actively carried out in Teheran. A relatively high rate of about 8% in the transport and communication industry is probably due to the fact that the present traffic system in Teheran is heavily dependent on automobile.

Comparison of the above with the nation-wide employment structure shows a wide difference as shown in Table 2-1-7. This indicates the fact that while Iran is still dependent on agriculture and fishery, the city of Teheran, as the most advanced city of Iran has the employment structure similar to that of the western countries.

Table 2-1-7 Employed Population by Major Industry Group in Iran 1966

	Total		Male		Female	
	Number	Ratio %	Number	Ratio %	Number	Ratio %
Agric., forestry, hunt and fish	3,168,515	46.1	2,965,287	40.9	203,228	22.4
Mining and quarrying	26,312	0.4	25,911	0.4	401	0.0
Manufacturing	1,267,600	18.5	758,799	12.8	508,801	55.9
Construction	509,778	7.4	507.703	8.5	2,075	0.2
Elec., gas, water and san. serv.	52,858	0.8	52,165	3.7	693	0.1
Commerce	552,023	8.1	543,096	9.1	8,927	1.0
Transport, stor. and Commun.	224,088	3.3	221,531	3.7	2,555	0.3
Services	929,685	13.5	759,718	12.8	169,967	18.6
Activities n.a.d.	127,539	1.9	114,203	1.9	13,336	1.5
Total	6,858,396	100.0	5,948,413	100.0	909,983	100.0

One of the outstanding features of employment structure in Teheran, which is also true with entire Iran, is that the percentage of employed women is extremely low as shown in Table 2-1-8.

Table 2-1-8 Employed Population by Sex - Teheran, 1966

	Total	Male	Female
Population	2,719,730	1,425,606	1,294,124
Employed population	755,174	687,182	76,992
Persentage of employment	27.8%	47.6%	5.9%

While the percentage of employed men is 47.6%, that of women is only 6.0%. As a result, the percentage of total employments for the total population is such a low figure as 27.8%. This low employment rate for women is attributed largely to the historical and religious backgrounds of Iran.

Breakdown of the total employment by major occupation is shown in Table 2-1-9. The table shows that the production workers have the largest share

Table 2-1-9 Employed Population by Major Occupation - Teheran, 1966

	Total		Male		Female	
	Number	Ratio	Number	Ratio	Number	Ratio
Prof., Tech. and related workers	61,474	8.1	39,594	5.8	21,880	28.4
Admin. and manage workers	6,815	0.9	6,562	1.0	253	0.3
Clerical and related workers	82,764	11.0	73,608	10.8	9,361	12.2
Sales workers	114,215	15.1	112,953	16.7	1,262	1.6
Service workers	116,518	15.4	84,279	12.7	32,239	41.9
Agricultural workers, etc.	8,775	1.2	8,651	1.3	124	0.2
Production workers, etc.	307,402	40.7	297,817	43.9	9,585	12.4
Workers not class. by occupation	57,206	7.6	54,918	8.1	2,288	3.0
Total	755,174	100.0	678,182	100.0	76,992	100.0

of 40.7%, followed by service workers and sales workers, each having a share of about 15%. The lowest rate is for administrative and management workers which account for less than 1%.

2.1.4 Present Land Use

Following a rapid increase of population in Teheran in recent years, development of new towns on the outskirts of Teheran has been carried out on a large scale, creating a new urban area linking neighboring cities of Shemiran, Rey and Kan, and covering an area of 215 km^2. Present land use map of Teheran is shown in Fig. 2-1-2.

In this region, however, the so-called sprawl phenomenon which is often seen in large cities of other countries is not so conspicuous. This mainly due to the outstanding leadership in administration and continuous efforts on the part of city authorities.

Commerce and business activities are concentrated on the center of Teheran city. Bazars are forming the core of wholesale and retail activities. Shopping areas are also seen in the neighboring cities such as Tajrish and Rey. Business activities are concentrated in the center of the city forming central business district with administrative offices. Private business activities centers around Ave. Ferdowsi and Ave. Pahlavi but new business districts are now emerging in the north around Ave. Takte Jamshid.

As for industrial activities, light industries are seen in the densely populated city area in the south, mostly in the southern area around bazar, and brick factories are seen in further south on the outskirts of the city. Meanwhile, such advanced heavy industries as automobile industry, machine tool manufacturing and electric equipment industries are developed mainly in the area along the Karaj Road, west of Mehrabad Airport.

For residential area, besides the new town areas under a large scale housing project in Teheran Pars in the east and Amirabad in the west, construction of private homes is being progressed on a large scale in the north, on the outskirts of Abbass-Abad. As far as the climate is concerned, the north is more favorable than the south for residential area.

In the south, urban environments have been deteriorating as well as extremely densely populated residential districts around Central Station of the State Railways. Improvement of these conditions is now being carried vigorously with the construction of apartment houses.

Population density in the north including Shemiran is about 40 persons/ha. but that of the highly populated area in the south is well over 350 persons/ha. with the average of the entire city area being 95 persons/ha.

2.1.5 Transport Facilities

Traffic in the city of Teheran consists of such vehicular traffics as private cars, buses, taxis and pedestrians. There is no railway system available at present as a means of urban transportation. There is a State Railway operating in the south of the city but because of its low operating frequency, coupled with low speed of train and high fare, this system is not being utilized as urban rapid transit. Meanwhile, automobiles have come to play a major role in the urban transportation. However, with the increase of the population and the growing number of automobiles, the road traffic is now under heavy pressure.

(1) Roads

The highways linking Teheran with other major cities of the country are the Route 7 and Route 4, which deploy in the west of Teheran connecting the coast of the Caspian Sea, Rasit, Tabriz and further extending to European countries, the Route 6 (overlapping the Route 7 in some section) and Route 8, which deploy in the south of Teheran, connecting to the central and southern regions including Esfahan and Shiraz and the Route 6 and Route 9 deploying in the east of Teheran to link key regions in the east including Sari and Mashad. Among them is the Teheran-Karaj Super Highway, a toll road originating in the west of Teheran and reaching the south of Karaj, is the only expressway in this country, which was built according to the standard of highway construction providing access control.

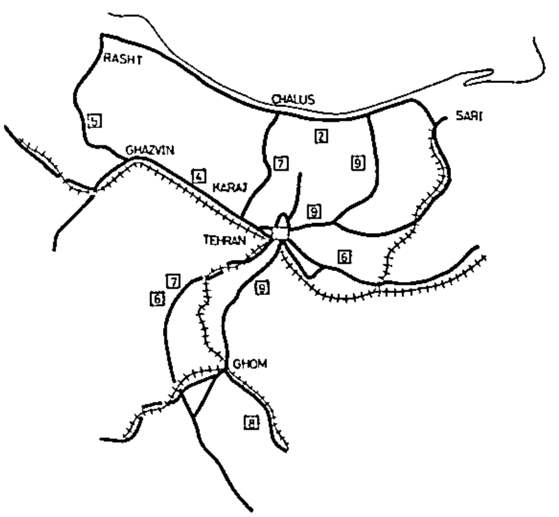


Fig. 2-1-3 Highway network around Teheran

In this country, the railway system has not yet been developed to satisfy transport demands for inter-regional as well as intra-city traffic, so vehicular traffic is playing an important role in these fields.

As stated previously, the transportation system in Teheran mainly depends on vehicular traffic and accordingly, the road conditions are generally satisfactory. Roads of various sizes run through the city in the grid pattern.

As for the road coverage in Teheran by road width, the so-called primary streets having a width of 24-40m (average 30m) is 250 km in the total length and 4.6 km^2 in the total area and the secondary streets having a width of 10 - 24 m (average 20m) have a total length of 1,100 km and a total area of 7.6 km^2. The local streets of small width run through the city area in all directions and the road area of these streets totals 27.2 km^2. Aggregated road area of the city is 39.4 km^2 with the percentage being 21.7%, which is far greater than 11.6%, the average of Tokyo and Osaka in Japan and is close to the Standard of European cities such as London and Paris. However, there seem to be various problems in the way each road is linked, or the forming of road network.

Streets like Ave. Pahlavi, Ave. Shah-Reza, which are the backbones of the present city area, were planned and built in 1930's in the early stage of the development of Teheran and therefore have failed to fully cope with a rapid expansion of Teheran and the progress of motorization so far, presenting several problems today.

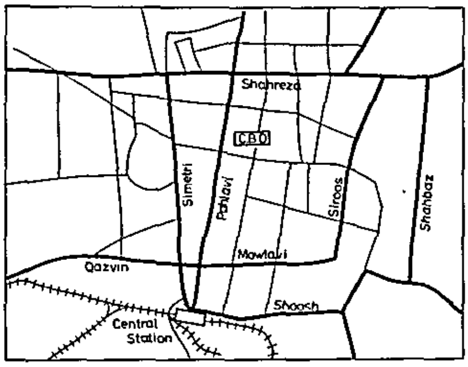


Fig. 2-1-4 Trunk road network in Teheran

First with the downtown commercial districts around bazar, the area has a historical background in the growth of Teheran and inherits the road network of the past. In the past there has not been any positive road improvement project and there still exist some trunk roads having dead ends. The only roads which really form a part of the trunk road network for the entire city area are the Ave. Shah - Reza, Ave. Simetri and Ave. Pahlavi. These roads could have played an important role as trunk roads in the day when the city activities were limited to a small range. However, in the age of automobile like today when the range of city activities has expanded tremendously, these roads can exist only to link local areas one another.

Meanwhile, as to the road network in the north and west of the city, where urbanization has been progressing rapidly in recent years, it seems that a full consideration has been given to the construction of road required for individual housing projects but there has not been careful planning for providing extensive trunk road network as an integral part of the housing development project, which is prerequisite to the housing project.

As for the parking of automobiles, the majority of automobiles are parked on the street. Parking of automobile on both sides of the street is a common practice and parking in the medial divider is also seen in some extreme cases. It is often seen that nearly half of the road width is used for parking. This situation is the main cause of obstructing effective utilization of roads which are otherwise under fairly improved condition. Of-street parking facilities covers an area of 500,000 m^2 but they are all small in size and it is said that there is only one parking lot in the city, which has a capacity of more than 100 cars.

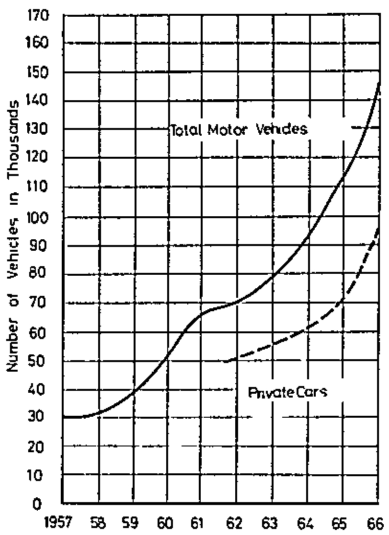


Fig. 2-1-5 Motor vehicle registration trend (1957-1966)

(2) Number of Registered Automobiles

The number of automobiles in Teheran registered 30,000 in 1957 as shown in Fig. 2-1-5 but it rose to 145,000 in 1966, an increase of nearly five times in 9 years. Table 2-1-10 shows the composition of registered automobiles in 1966 by vehicle type. According to the table, private cars number 85,500, accounting for nearly 60% of the total vehicles, followed by motor cycles, trucks, and taxis in that order.

Table 2-1-10 Number of Registered Automobiles in Teheran by Type - 1966

Type	Number	Ratio
Private automobile	85,500	59.0%
Government and diplomatic car	7,600	5.2
Taxis	8,000	5.5
Bus	3,000	2.0
Trucks	12,000	8.3
Motor cycles	29,000	20.0
Total	145,000	100.0

The average annual growth rate of private cars was around 18% during the period from 1962 to 1966 but it jumped to 35% in 1966 over the previous year. As a result, the number of private cars per 1,000 population rose from 20 in 1962 to 28.5 in 1966. Factors contributing to this rapid growth of the number of automobiles are considered to be (a) A sharp increase of population, (b) the growth of economy, particularly the increase of income and (c) the growth of automobile industry.

(3) Bus

The bus is playing a major role in Teheran as a means of public transport and is available at a low fare with its route covering a considerably large area. As shown in Fig. 2-1-6, the number of bus routes in the city as of 1967 was 110 with 1,600 buses in operation. However, because of jamming road

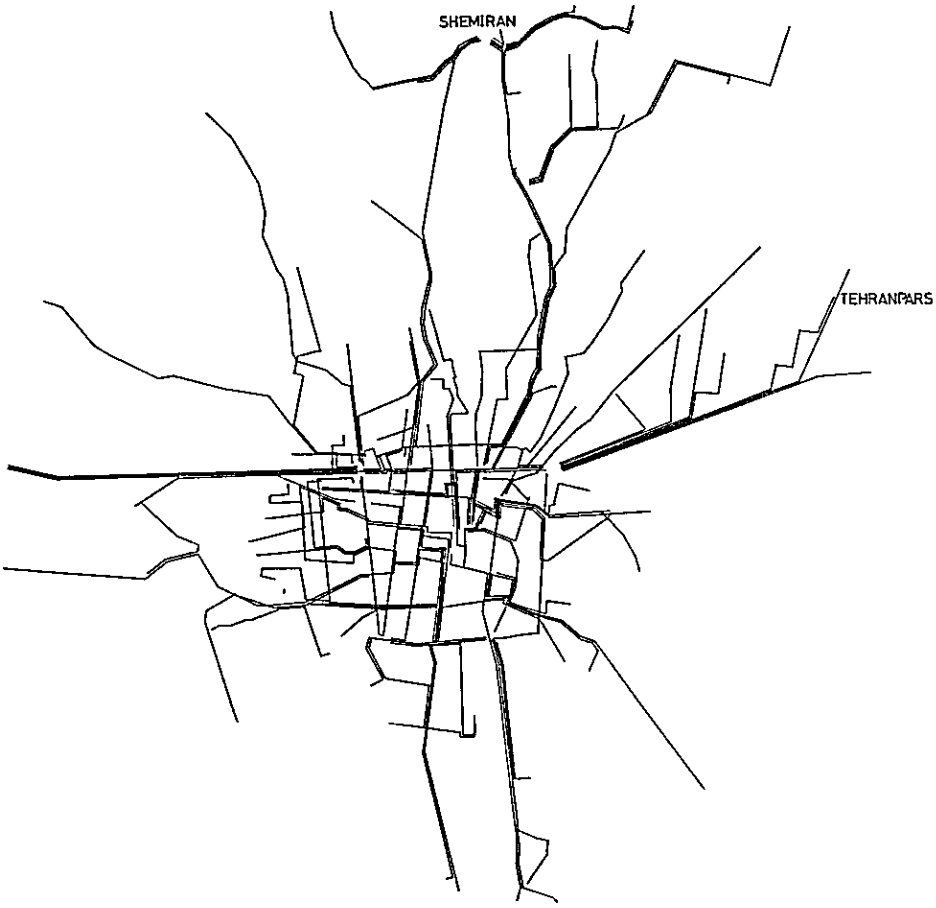


Fig. 2-1-6 Bus routes in Teheran

traffics, the speed of bus is at around 20 km/h, indicating the need for the construction of subways or improved bus transportation service through reorganization of the existing routes or by giving priority to bus traffic over other traffics. Besides, 1,000 buses are put in daily operation for intra-city service.

(4) Taxi

The taxis in Teheran have two types. One is the so-called common taxi and the other is the route taxi which picks up passengers like omnibus and operates on specific route. The total number of taxis now in operation is 8,000 of which 6,200 are common taxis and the remaining 1,800 are route taxis. Mainly because of low fare, the taxi is very popular but there seems to be a shortage of taxi against a growing demand.

(5) Truck

The majority of freight transportation in Teheran are by trucking.

The truck registered for intra-city cargo transportation numbered 8,900 as of 1967, of which about 8,000 are now operating in the city daily, handling almost all the cargos of the city. There are 55 truck terminals located mainly along the roads to Rey, Qazvin, Shiraz and Shoush. However, these truck terminals are not provided with adequate spaces for loading and unloading of cargos and their functions are limited only to providing parking spaces for trucks.

In Teheran the traffic of truck is not allowed in business and commercial districts during business hours.

2.1.6 Traffic Volume

The total number of trips in Teheran is 9.8 million, and the number of trips per capita is estimated to be 3.27. Breakdown by the means of transportation for the above total number of trips is shown in Table 2-1-11. According to the table, trips by pedestrian have the largest share, accounting for nearly 60% of the total trips, or 5.8 million trips.

Table 2-1-11 Number of trips in Teheran by type of transport

Type of transport	Number of trips/day (ten thousand)
Bus	190
Common taxi	30
Route taxi	30
Private car Governmental and diplomatic car	80
Motor cycle	20
Bicycle	50
Sub-total	400
Pedestrian	580
Total	980

Next comes the bus with 1.9 million trips, accounting for 20%, followed by private car with 8% and taxi with 6%. Trips by bicycle accounts for 5%.

Breakdown of all trips by purpose is shown in Table 2-1-12. According to the table, main purposes are home, accounting for 42.7%, followed by work with 19.2%, shopping with 16.3% and school with 11.1%. It is noteworthy that the trip for business have an extremely low rate of 2.3%.

Table 2-1-12 Number of trips in Teheran by purpose

Purpose of trip	Total in miles	Trips per household	Trips per person	% of Total
Home	4.19	6.60	1.40	42.7
Work	1.88	2.97	0.63	19.2
School	1.09	1.72	0.36	11.1
Shopping	1.60	2.52	0.53	16.3
Business	0.23	0.36	0.08	2.3
Visits	0.36	0.57	0.12	3.7
Movies	0.05	0.08	0.02	0.5
Restaurant	0.21	0.33	0.07	2.2
Others	0.19	0.30	0.06	2.0
Total	9.80	15.45	3.27	100.0

Breakdown of all road traffic volume by vehicle type shows that passenger cars (total of private cars and governmental and diplomatic cars) have a largest share, accounting for 45.5%, followed by taxis accounting for 29%, buses 5%, trucks 2.5% and other vehicles for 18%. Comparison of this traffic volume with the number of passengers by type of transport shown in Table 2-1-11 indicates that the traffic volume of passenger car is considerably large compared with the number of its passengers, on the contrary, buses transport a far large number of passengers with its small traffic volume.

On the general traffic pattern based on the result of traffic surveys conducted in the main streets between 6 a.m. to 10 p.m. in the winter season, the traffic on a weekday ranges from 22,000 to 68,000, with the average being 31,000. On Thursday, the average traffic is 29,000 but there is a wide difference in traffic volume depending on roads, ranging from 18,500 to 77,500. On this day some roads have more traffic than on weekdays. Traffic volume on Friday is considerably small compared with that on other weekdays. On the fluctuation of traffic volume by hour as shown in Fig. 2-1-7, the peak traffics on weekdays and Thursday are seen between 5 p.m. and 6 p.m. followed by the morning rush hours, which is from 7:30 a.m. to 8:30 a.m. This is mainly due to the difference in the working hours, as shown in Table 2-1-13, in which the traffic in the time zone of

Table 2-1-13 Working hour zone

Place of work	Working hour zone
Private office	8-12 a.m. and 1-5 p.m.
Shops	8-12 a.m. and 4-8 p.m.
Government office	7:30 a.m. - 1:30 p.m.
Industries	7:00 a.m. - 3:00 p.m.

5:00 p.m. to 6:00 p.m. is by the people on the way home after completing the day's work and the people on way to work plus shopping people. On Friday, the peak traffic is between 11 and 12 in the morning with the rate of concentration being 9.4% compared to 8% on weekdays.

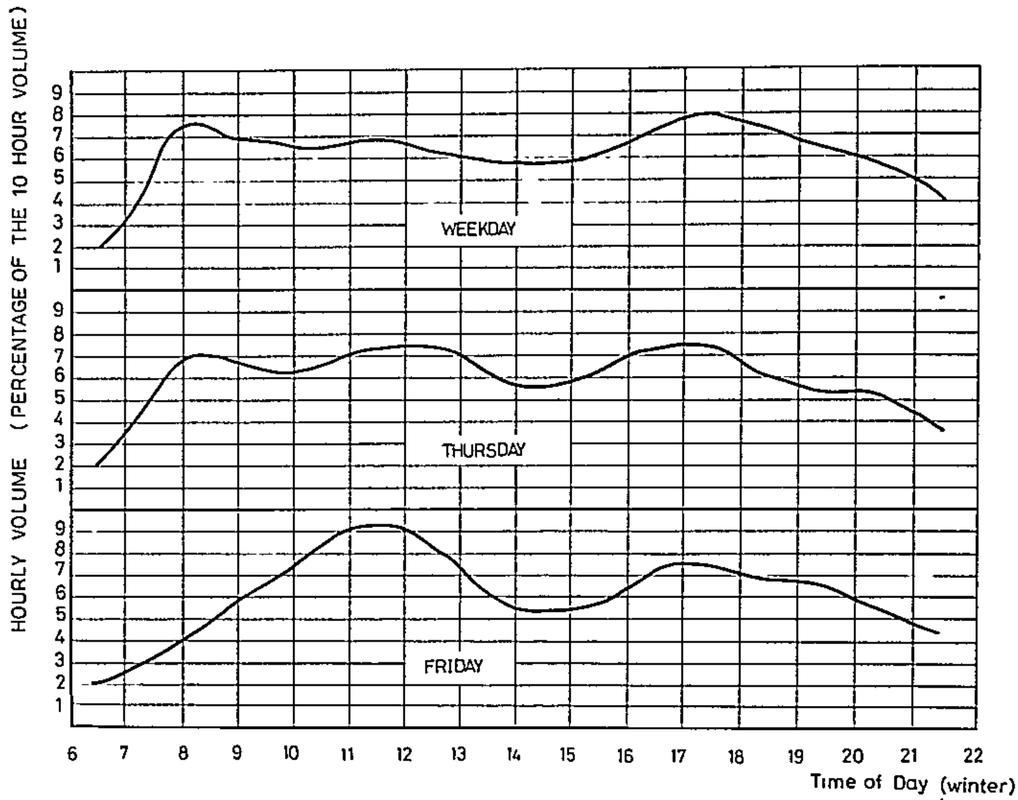


Fig. 2-1-7 Daily traffic pattern in Teheran

Fig. 2-1-8 shows hourly fluctuation of traffic volume at the key points in each major road. This figure, which is based on the traffic count conducted in late July of 1969, also shows the peak traffic in the 7:00 p.m. - 8:00 p.m. time zone in addition to the peak in the morning and afternoon, the pattern slightly different from the average pattern. This late hour peak is probably due to the car traffic for Tajrish to seek the evening cool in addition to the traffic heading home after the day's work. During this hour the traffic on the roads running from south to north such as Ave. Pahlavi reaches 2,500 - 3,000 vehicle/hr. in one direction.

Traffic volume on these roads during daytime (8:00 a.m. - 8:00 p.m.) is as follows:

Ave. Pahlavi (near Ave. Rasht)	23,000 vehicles
" (near Taktefavos)	30,600 "
Ave. Eisenhower (near Bemeh Builp)	31,400 "
Ave. Simetri (near the police station)	15,500 "
Ave. Shah Reza (in front of Palace Hotel)	33,400 "
Ave. Ferdowsi (down Ave. Shah Reza)	35,700 "
Ave. Takte Jamshid (between Villa and Ferdowsi)	24,000 "

From this it may be said that the traffic on the majority of trunk roads are near saturation except the 2:00 p.m. - 4:00 p.m. time zone.

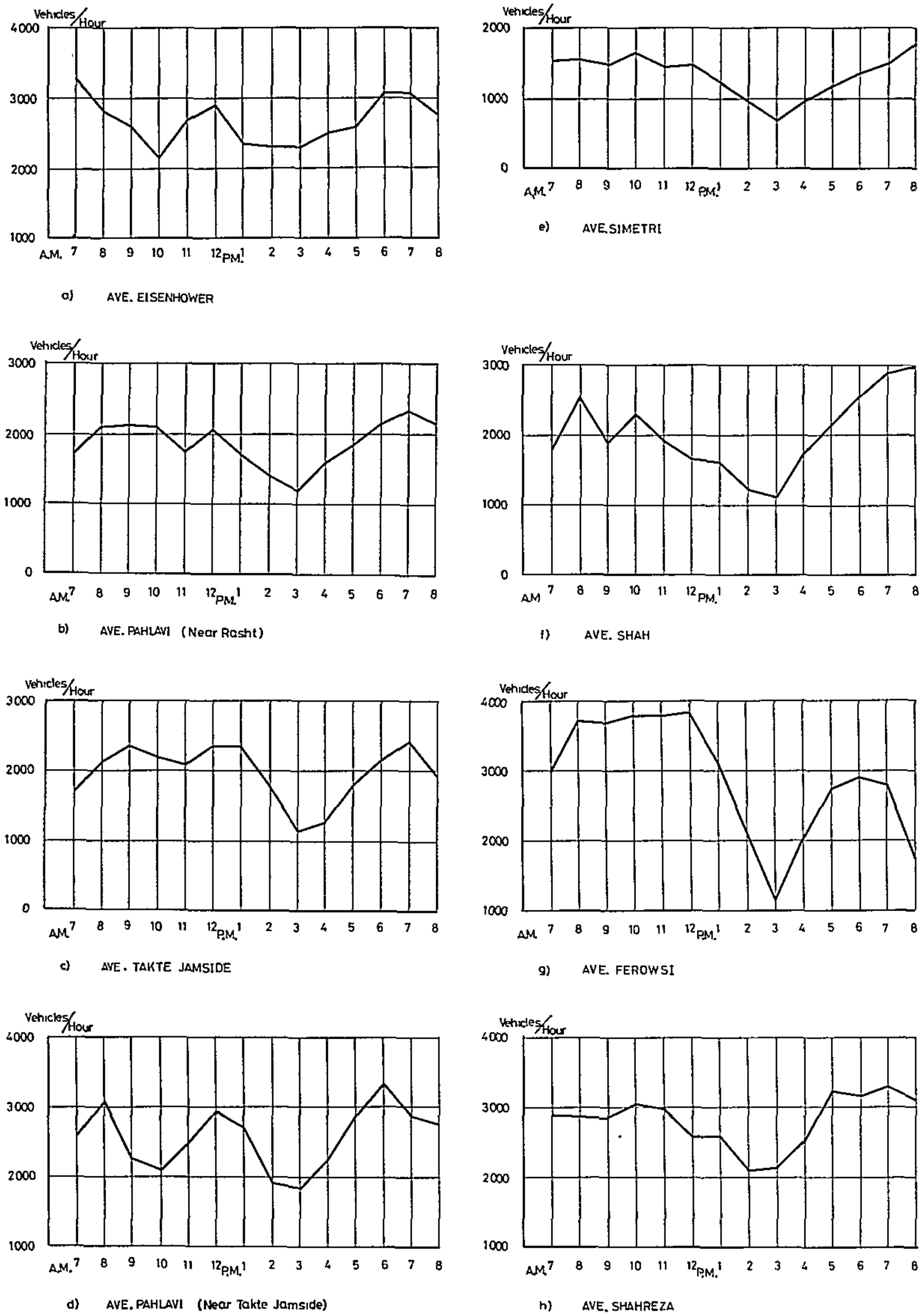


Fig. 2-1-7 Traffic volume on major roads

Table 2-1-14 Inter-city Transportation

Type of transport	Passengers (persons/day)	Freight (ton)
Bus	27,000	
Railways	4,700 (10 trains)	4,500
Truck	-	36,000
Airlines (40 flights)	1,700 (Foreigners accounts for 40%)	5
Passenger car	183,000	40,500
Total	216,400 persons/day	81,005 ton

Finally, on the inter-city traffic, Table 2-1-14 shows that the number of passengers is about 217,000 daily, of which 183,000 or 84% are by passenger cars and the majority of the remainder are traveling by bus, with almost negligible share by railways and airlines.

2.1.7 Freight Transportation

Freight transportation within the city of Teheran and between the city and outlying areas are mostly by trucking. Trucking within the city area is shared by the intra-city agencies which handle about 4,500 tons daily, individual truckers with 3,000 tons and the self-transportation with 1,000 tons, a total of 3,500 tons.

For the transportation between the city and outlying areas, trucking accounts for the majority with 36,000 tons, followed by railways which transport 4,500 tons by its 22 trains. By destination, the Karaj Road which extends to the west handles 15,000 tons accounting for more than 40%, followed by the Mazandaran Road and the Khorasan Road, both handling about 5,000 tons of cargos, respectively.

2.2 Basic Plan

2.2.1 Population Plan

If the present trend is to continue, the population of Iran is expected to reach 50 million in 1991. For Teheran city, if the present pace of growth is to continue, the population may exceed the 10 million. However, under the precondition assigned, the population in Teheran is to be held below the 5.5 million

Table 2-2-1 Future Population of Teheran city

Year	1966	1971	1976	1981	1986	1991
Population (in millions)	3.00	3.83	4.53	4.95	5.23	5.55
Growth Rate (%)	100	128	151	165	174	185

mark through countermeasures such as imposition of limits on the concentration of industries, because of water supply capacity. In other words, the pace of growth in the population in Teheran will decrease sharply in the course of years and the population is expected to reach 5.5 million in 1991. The total city area then will be 600 km^2 and the density of population per km^2 will be 9,000.

On the distribution of the population within the Metropolitan Area, the plan envisages the establishment of 10 districts, each having a population of about 500,000 and its own city center within the district, through renewal of the existing city area and development of the outlying area. In other words, the city will further expand to the east and west to include Bardabar, Ratoman, Kan, Amirabad, Abbas-Abad, Teheran Pars and to the south to north to include Shemiran, Teherancores, and Rey, with each district forming an independent block.

2.2.2 Industry and Income Program

Economy of Iran will also maintain a high growth rate in the future and the G.D.P. is expected to grow by an average rate of 7.0% to more than five times the present level in the next 25 years by 1991. Ther per capita income, when the increase of population is taken into consideration, is expected to grow at the rate of 4.4%.

Economy of Teheran city will probably slow down in the next 25 years, dropping gradually from the present 9.6% to 5.4% but will maintain the average growth rate of 6.8% and its share in Iran will probably remain the same. Per capita income in Teheran will grow at the rate of 4.4%, from 45,000 Rls. in 1967 to 140,000 Rls. Reflecting such high economic growth, employed population will also increase to 1,815,000 from 755,000 in 1966, an increase of 2.4 times, and the percentage of employment will also grow to 33%.

Breakdown of employment by industry is shown in Table 2-2-2. The table shows that the employment in commerce will have the largest share with 777,000, accounting for 43%. Depite the restriction imposed on the concentration of industries in the city area, restriction of the growth of manufacturing industry is almost impossible and the employed population in this field will reach 508,000, accounting for 28%. Teheran, as the center of politics will also see further concentration of government functions within the city and the employed population in government service will reach 424,000 or 23%.

Table 2-2-2 Future Employed Population by Industry - Teheran, 1991

	Number employed	% of total	Sectoral break-down in %
National government	335,000	18.46	66.17
Local government	89,000	4.90	
Basic comerce	472,000	26.01	
Non basic commerce	305,000	16.80	
Basic manufacturing	273,000	15.04	27.99
Non-basic manufacturing	235,000	12.95	
Agriculture and mining	15,000	0.83	0.83
Other (including unemployed)	91,000	5.01	5.01
Total	1,815,000	100.0	100.0

2.2.3 Land Use and Land Development Plan

The proposition on the use of land as a precondition of working out transportation system in Teheran is as follows.

1. The population of Teheran in 1991 is to be 5.5 million.
2. The scope of future urbanization program is to cover an area of 600 km^2 and the area coverage is to be as shown in Fig. 2-2-1.
3. The city area is to be divided into 10 zones as shown in Fig. 2-2-1, each having a population of 500,000.
4. Each zone is to be independent one another and to create its own business and commercial center within zone.

These conditions are based on the concept which envisages the development of Teheran in "linear pattern" from east to west.

The main functions of large cities are so-called centralized managements which requires a great deal of information, so it will be expected to concentrate still in the present center of Teheran even in the future. Consequently, smooth traffic and communication between these new sub-centers and present center of Teheran will become an important proposition.

These new sub-centers will naturally provide administrative, commercial and business services for the daily life of the people as the main functions of each zone. Though the details of these functions are not clear yet, the plan must estimate a considerably large quantities of business and commuting trips between those sub-centers and the present city center. A heavy industrial district is to be established in the south along the Karaj road. Adoption of industry dispersion policy will probably accelerate the establishment of industrial bases in rural area but there still seem to be a enough land for industrial productions to supply to the future Teheran with a population of 5.5 million. Those industries will need industry workers of about 240,000 and industrial area of about 5,000 ha.

Residential area is to be distributed to each zone and the hilly districts north of the Karaj Road will be developed as a large scale residential district. The area around each train station, within a radius of about 500 meters from a train station of rapid transit such as the subway will be developed to a highly populated residential district and the area far from a station will be developed as less populated residential districts.

The development of Teheran should be planned as a part of the development project for the belt zone including Karaj and Qazvin under the National Development Plan including the development of under developed area such Caspian coast and inland area and the Persian Gulf coast.

2.3 Traffic Planning

2.3.1 Traffic Demands

(1) Forecast of Traffic Demands

The region including Teheran and extending to Karaj and Qazvin has the greatest potentiality of growth in Iran. Because of its excellent land,

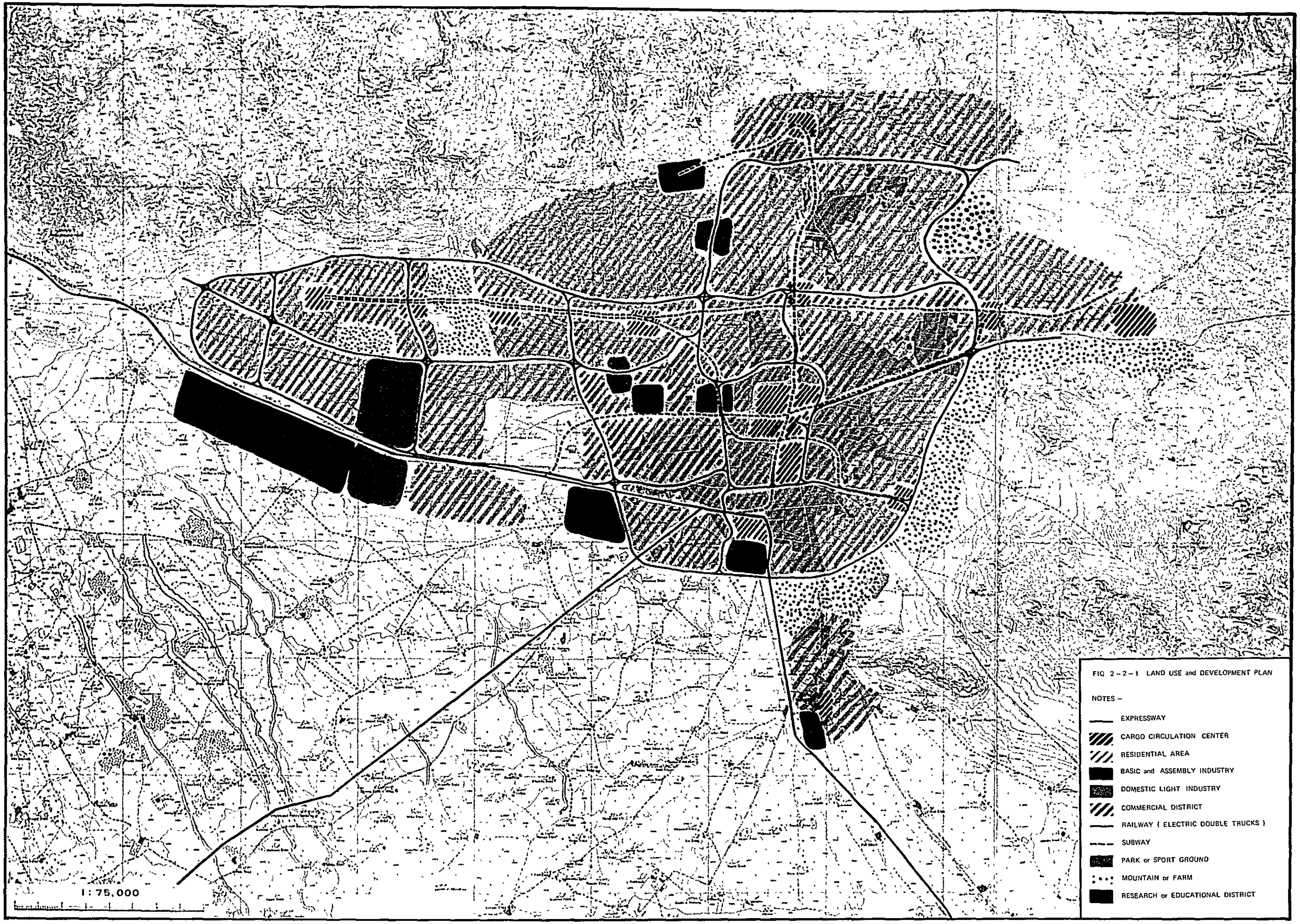


FIG 2-2-1 LAND USE and DEVELOPMENT PLAN

abundant water and its location for the full use of information from the capital city, and transportation, the flow of population into this region will never cease and there will be serious problems of overpopulation.

For this reason, the forecast of future traffic demands must be based on a reasonable land use plan. In other words, by fixing the total population of the Teheran Metropolitan Area at 5.5 million, it's total land space at 600 km^2, dividing the Metropolitan Area into 23 zones, the floor space by zone and use will be calculated from the flow chart shown in Fig. 2-3-1. The traffic volume between each zone of 23, will be computed by using Gravity Model Method, on the basis of numbers of traffic generations in each zone, distance between each zone, with the number of unlinked trips totaling 26.4 million trips and that of linked trips totaling 18 million trips.

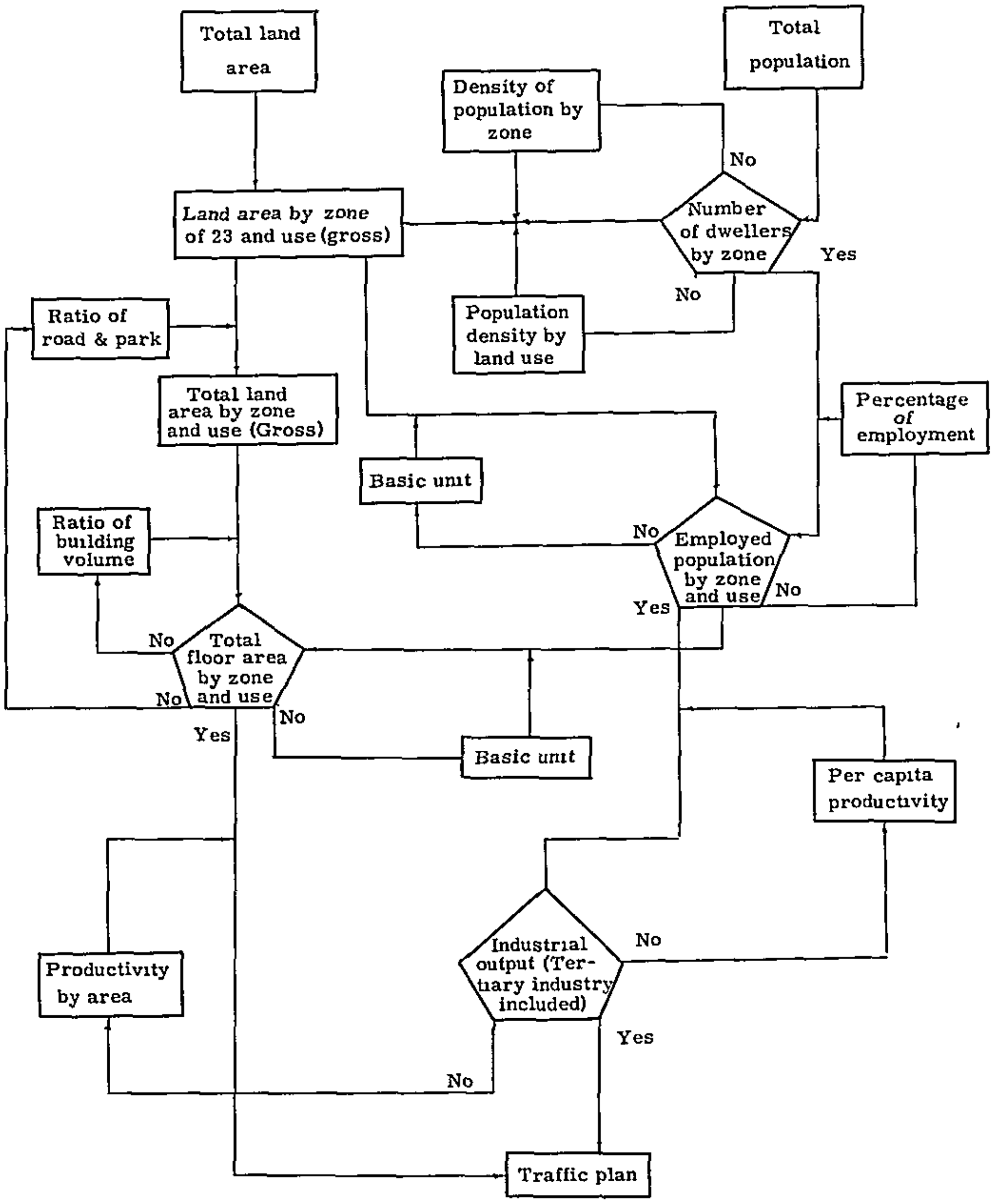


Fig. 2-3-1 Flow Chart for Computation of Traffic Generation by Zone

With 26.4 million unlinked trips, as the controled total, amounts of industrial output, number of automobiles, population density, percentage of employment, characteristics of Teheran as the capital city and experimental coefficint of Gravity Equation in Hiroshima, Japan, have been taken into consideration in the computation. Traffic volume between each zone has been obtained through iteration by a computer. Table 2-3-1 shows traffic between Origin-Destination by classifying the zone into (A) Existing city area, (B) Suburbs of existing city area and (C) Outlying new sub-center area.

Table 2-3-1 Estimated Trip Number

Unit : Trip/day

O \ D	A	B	C	Total
A	5,784,857	3,207,741	634,662	9,627,260
B	3,207,741	6,468,837	1,772,363	11,448,941
C	634,662	1,772,363	2,898,181	5,305,206
Total	9,627,260	11,448,941	5,305,206	26,381,407

The table shows that the suburbs of the existing city area, including Abbas-Abad where new administration center is planned and the area where new sub-city-centers or residential districts are planned, are expected to see more commuting trips than in the existing city area in view of future structure of Metropolis, and the existing city area will see more trips for business.

(2) Modal Split by Means of Transportation

Modal split of traffic volume between each zone by means of transportation may depend on the purpose of trip, hours of trip, fare, comfort, and custom. But, for deciding the modal split, the basic units shown in Table 2-3-2 have been used by taking into account the characteristics of Teheran, results of surveys conducted in a large city in Japan, supposedly resembling to Teheran.

Table 2-3-2 Distribution of Traffic volume by type of transport (Modal Split)

Purpose of trip	Total trip percentage by purpose	Utilization of transportation					Rate of concentration on a peak hour
		Railways	Bus	Passenger Car	Foot	Total	
Office & school	25%	20%	25%	15%	40%	100%	40%
Business	35	10	15	25	50	100	10
Home	40	15	15	15	55	100	20
Total	100	average 15	17	18	50	100	

The number of person's trips concentrating on the business district in the downtown area is 4.4 million, of which the trip by transportation facilities other than foot trip is 2.6 million. With the rate of concentration on a peak hour being 25%, the number of trips using transportation facilities in a peak hour will be 660,000 trips.

If this figure is to be shared to rapid transit and vehicular traffic on the basis of purposes of trips and travel distance, the number of trips by rapid transit is estimated at 230,000 and that by vehicular traffic at 430,000.

Also, with the change of riding habit, utilization of mass transit will be characterisized by commuting traffic and business trips are expected to use positively passenger cars through expressways.

2.3.2 Basic Policy of Traffic Planning

The capital city, Teheran has such diversified functions as political, economical, commercial, industrial activities and residential districts. It will be important, therefore, to shift Teheran from the present single core pattern to the multi-core patter with divisional functions coordinating between the above functions.

For this purpose, it will be necessary to establish a firm urban transport system which will form a frame work of the new city pattern, as a matter of course, satisfying commutation and business trip demands, for the future. To attain this objective, it will be necessary to link various auxiliary traffic systems organically with the Metropolitan Rapid Transit Railways and the Urban Expressways.

It is hoped that these transport facilities will stimulate systematic development of outlying areas, and promptly link these areas with the existing city area timing with the start of its redevelopment.

Based on this concept, the basic policy should provide as the proposed Master Plan, a systematic linkage between existing city center and new city centers, and trunk lines as inter-city and inter-region transportation system.

2.3.3 Proposals for the Rapid Transit Railway and Urban Expressway Network

The rapid transit railway project includes the proposed construction projects of new subway and the improvement project of the State Railway. The subways are desired to form a network which is capable to provide a direct service to the future sub-centers with respective functions assigned, so that those major business districts can be covered within a walking distance from the nearest stations(Chapter 4). If the city develops in the linear pattern to the east and west direction, the scheduled speed of trains needs to increase in the suburbs, by about two fold of the ordinary speed in order to draw the residential districts nearer to the business districts by cutting down the travel time. The schedule of train operation on the State Railway is to be busy and the through train operation is needed between the State Railway and the subway, in order to secure the transportation of peoples and goods and to advance the activities in the daily living areas spreading out to a radius of 30 km from the center of Teheran. These traffic patterns may be regarded as the Turner System which enables passengers to reach any distination by one transfer. Four new rapid transit railways are hereby recommended. (See Fig. 4-2-1). Route 1 originates at the Central Station of State Railways, runs through Abbas-Abad and reaches Tajrish. Route 2 has connections to the State Railways in the south of the Mehrabad Airport, runs through the airport and present city center and reaches Teheranpars. Royte 3 runs through Kan, Amirabed, new sub-centers planned for the west, and present city center and reaches a new city center of Teheranpars in the east. Route 4, like Route 3, links new sub-centers in the south and reaches Abbas-Abad and Teheranpars.

The urban road network project includes the construction of urban expressway network, the improvement of trunk streets to increase their efficiency and the establishment of terminal buildings.

Under the urban expressway projects, it is proposed to form a network combining the ring pattern surrounding the present city center (Central Business District) with the ladder pattern serving sub-centers to be developed in the western direction (Chapter 3). This network is designed to contribute to the business activities including the commuting, the smooth distribution of materials between Teheran and other principal cities in the country. C.B.D. Ring Expressway which encircles Central Business Districts in the present city center and Suburban Ring Expressway which deploys approximately 6 km from the present city center are to be conceived. For the new city area which deploys in Karaj in the west and Tajrish in the north, Western Suburban Expressways and Tajrish Road, in ladder pattern, are to be conceived (see Fig. 3-3-4).

Further, the C.B.D. Ring Expressway can be provided with Branch Expressways to connect it to the proposed traffic terminals and off-street parking lots.in the city center.

In providing the parking lots and the traffic terminals, it is desired to construct terminal buildings in line with the urban renewal projects in the city.

CHAPTER 3 EXPRESSWAYS

3.1 Basic Policy of Planning

3.1.1 What a Road Network in a City Should Be?

The traffic of motor vehicles in a city varies both in quantity and quality. For example, there is through traffic that doesn't have its origin nor destination in the city, and external traffic with its origin or destination in the city, and internal traffic with both in the city. Further, the internal traffic includes various traffic such as traffic within the central business district, traffic between the residential and business districts, and the traffic between the industrial area and the commodity circulation center. The purpose of traffic is to transport to work places, schools, business, shopping, and recreation.

While urban roads must be able to accommodate these various kinds of vehicle traffic, they are not confined to deal only with this traffic. They not only have great influence on the formation of a city and the manner of land use but constitute themselves the open spaces in a city, as well as providing spaces for laying gas and water supply facilities.

In forming a road plan to meet this need it is necessary to layout various roads systematically on the basis of the present conditions and the future traffic trend.

Urban roads may be classified functionally into:

i) Urban expressway;
ii) Primary arterial street;
iii) Secondary arterial street; and
iv) Pedestrian road and cycle path, etc.

The urban expressways are usually planned with a high capacity for motor vehicle traffic in mind. They reduce time and distance thanks to the secured travelling on them with comparatively high speed.

The primary arterial streets which form the framework of the urban road network together with the urban expressways should be roads of high efficiency with the few intersections with other streets, and their principal intersections are grade separated. Usually, they comprise 4-8 lanes.

The secondary arterial streets positioned between the arterial and the local streets play a role of smoothly collecting and distributing vehicle traffic.

The local streets serve to roadsides area with a safe environment without through traffic. The local streets in a residential district may be purposely arranged staggeringly or impassably.

An expressway allows vehicles to travel on it comfortably without any stopping, but it is apt to paralize the speed sensitivity of the driver. Therefore, it is dangerous to connect the access ramp of an expressway directly to secondary arterial or local streets and is also undesirable in view of the balance of traffic capacities between these two roads. Various types of roads should be combined with each other so that traffic can be shifted in consequtive order from the higher standard road to that of a lower standard, thus establishing a harmonious road road network.

This may be expressed as shown in Fig. 3-1-1.

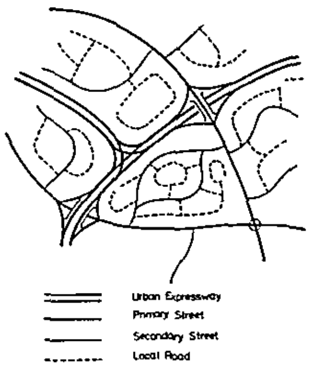


Fig. 3-1-1 Road network pattern

3.1.2 Need of Expressway

The operational aspects of streets will be dealt with in detail especially in Chapter 5, Some considerations will be made here from the standpoint of road network. The arterial road network in the city of Teheran is in a grid pattern with 4-6 lanes, and it's capacity is already inadequate for the present road traffic, resulting in an impending paralysis. In order to secure a smooth flow and to cope with the expansion of the city and the increase in vehicles, it will be necessary to set up an arterial road network in the Teheran Metropolitan Area with roads capable of a great capacity and high speed. To widen the existing surface streets on a large scale to serve this purpose is not only practically impossible but is unadvisable both economically and technically.

It is believed that the most desirable and practical solution is to introduce an urban expressway network as the fundamental road network of the city, and to reconsider what the street network should be in correlating with it systematically.

Although we are pleased with several plans prepared by the city authorities for the area north of Av. Shahreza, and some of which are being gradually implemented, the urban expressway network should be first on the list and must be done in a hurry.

The 4th Five-year Plan consists of the construction of a five arterial road around Teheran, including the Teheran Ring Road (100 km). The Japanese Survey Team is going to propose that the urban expressway network in the Teheran Metropolitan Area.

Improvement of the existing streets, particularly the pavement on footways; improvement of intersections; provision for pedestrian bridges and a regulation to keep the through traffic from entering local streets, are to be executed in addition to the construction of the arterial roads referred to above.

3.2 Expressway Network Pattern

3.2.1 Basic Pattern

The number of registered vehicles in Teheran is estimated to be about one million in 1970 and the number of trips is expected to reach 3.3 million. In order to deal with such a great volume of traffic smoothly, it may be well to promote the improvement of streets. However, since there is a limit to the widening and new construction of streets, it has become a tendency in large cities of the world at present to introduce urban expressways as a more effective means. As a matter of course, Teheran is not an exception; the urban expressways should be projected as a means to deal with in mass the traffic concentrated in and dispersing from Teheran and the intra-city traffic moving comparatively great distances.

In general, there are two patterns conceivable for the urban expressway network; that is, the grid pattern and the combination of radial and ring pattern. Almost of all the cities in the world have adopted the latter pattern around the central commercial and business district as its center.

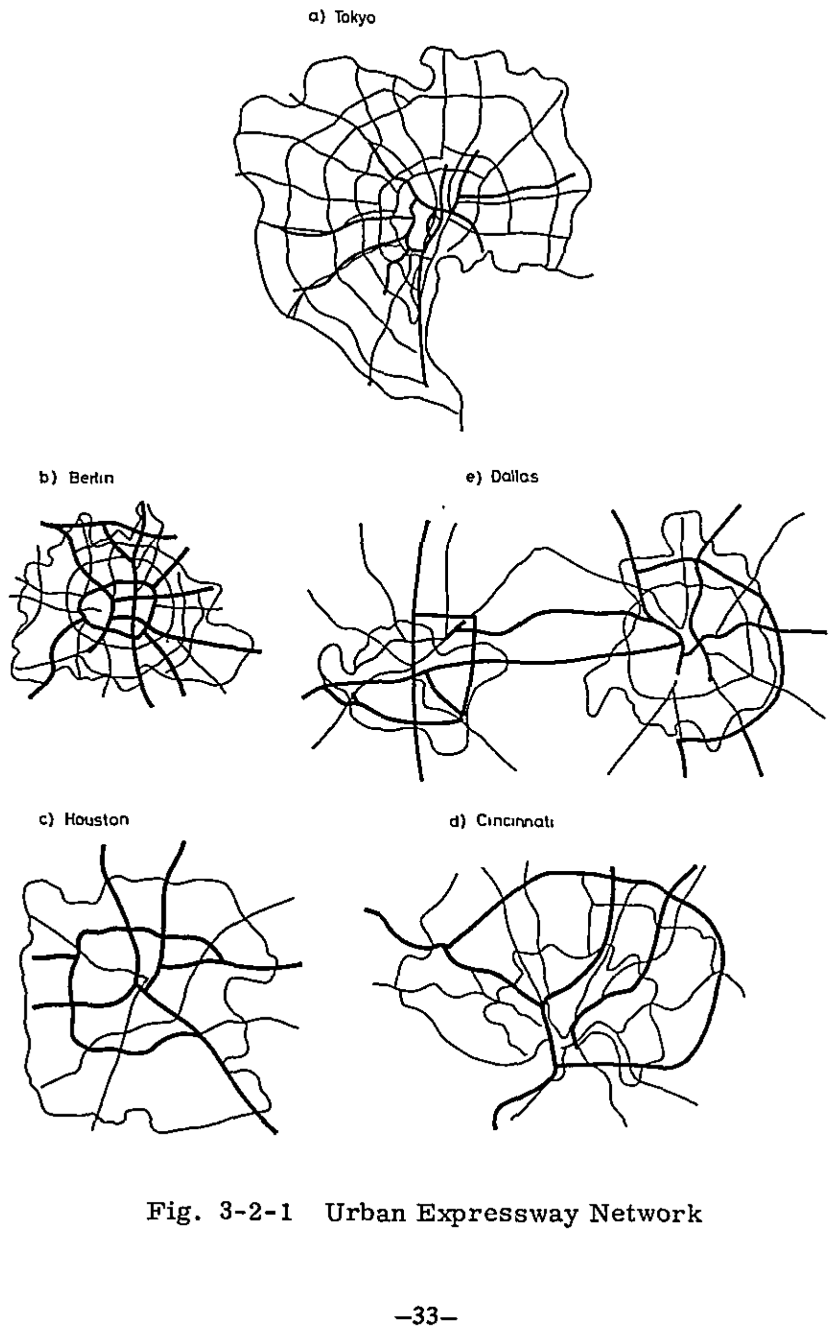


Fig. 3-2-1 Urban Expressway Network

This is a natural conclusion in meeting the traffic demands generated predominantly in the city center. If the whole urban area is to be served by the expressways in grid pattern network, some sections near to the city center will carry an excessive traffic volume, making it difficult for the entire network to work effectively.

The grid pattern network causes an unbalance in traffic volume on the main roads. The access ramps near the city center will constitute large bottlenecks due to their limited traffic capacities. On the contrary, the combination of the radial and ring pattern surrounding the Central Business District serves the city center by dispersing traffic through several ramps on the ring road, reducing such problems as above mentioned. In relation to land use, since the grid pattern necessarily passes through the city center, its construction requires a clearance of the built-up area. The ring pattern can be formed on the outer side of the city center, with relative ease in construction.

In locating the radial roads, it is needless to say that since the existing urban area is generally formed in a grid pattern, adequate care should be taken not to destroy these blocks unnecessarily.

3.2.2 Pattern for Teheran

From the standpoint of the above considerations, we plan to construct an expressway network shaped in a combination of radial and ring type in the existing urban area of Teheran and its environs.

However, in the direction toward Karaj of which future development is expected, it is proper tooconstruct the expressway network in a grid pattern so as to serve zones, each being a unit of about 500,000 population, which are to be spread out linearly.

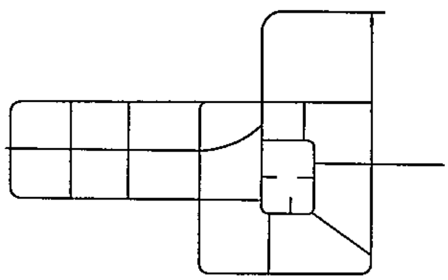


Fig. 3-2-2 Conceptional expressway network for Teheran

Therefore, we are conceived that the expressway network combined in these two patterns is the most desirable pattern for the Teheran Metropolitan Area in the future.

The urban ring expressways are inner ring expressways around the Central Business District (here after referred to as C.B.D. Ring Expressway) and the outer ring expressway (hereafter referred to as Suburban Ring Expressway) surround the city running through its environs.

The former is intended to deal with a large volume of traffic generated in the city center, while the latter is to smoothly connect the inter-city expressway to the arterial streets and C.B.D. Ring Expressway.

The method of connecting the inter-city expressway with the urban expressway presents a great problem. As shown by the recent examples in large cities, it is deemed desirable to accept inflowing traffic from the inter-city expressway by an outer ring expressway so as to distribute the traffic into the outskiars

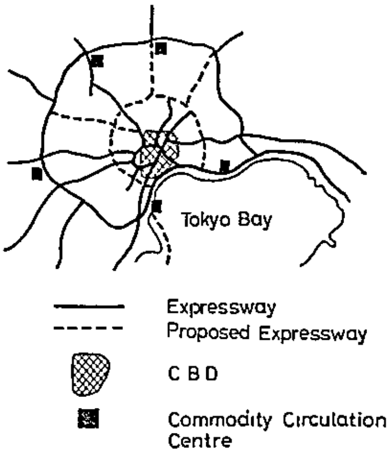


Fig. 3-2-3 Location of commodity circulation center in Tokyo

before introducing it into the urban area, instead of allowing it to enter directly. The ring expressway planned as such serves as a by-pass for through traffic having no business within the city. Moreover, it creates the possibility of rearranging the distribution facilities such as the Commodity Circulation Centre, storehouses and terminals located dispersely in the existing urban area. It is possible to collect them on the spacious land along the Suburban Ring Expressway.

These two ring expressways should be connected by a radial expressway.

In order to secure good service in the central business district from the C.B.D. Ring Expressway, the plan is to construct several Branch Roads going to the city center, in addition to the ramps provided on the C.D.B. Ring Expressway, directly connected to terminal buildings with ample parking lots to be built in the city center.

To serve the developing area in the direction of Karaj, the plan is to construct 3 expressways; one built parallel to the existing Teheran-Karaj Expressway linking the residential districts on the north side; another built along the railway on its south side running chiefly through the industrial zone (West Suburban Expressways).

These two expressways are to be connected by several routes running from south to north to complete the grid pattern network.

The routes to be built on the north side need to be extended in the direction of Tajrish, Chiras to serve the residential districts north of Teheran.

3.3 Route Plan

3.3.1 Policy of Route Selection

In drafting the plan of the urban expressways for Teheran, we have paid special attention to the following points.

i) Since it is expected that the construction of expressways in the existing urban area will be restricted technically in various aspects in the execution, the plan must have technical possibilities in the face of these limitations. At the same time, attention should be paid to the economical aspect and the minimum construction cost should be sought. Because it requires a huge sum of money to acquire land and to move houses on a very large scale in order to construct urban expressways in the existing urban area, the utilization of public land will be employed as much as possible and we propose to construct some sections of the projected expressways over the existing roads as elevated expressways.

ii) Since the expressway network should function effectively in a body with the general street network, adequate attention will be paid to its connection with the main arterial streets in order to avoid a traffic paralysis on the streets.

iii) The expressway network can meet with the traffic demands at the time of completion, but it must be able to deal with the traffic demands effectively even when it is partially opened to use.

iv) The streets in Teheran are beautiful by attired with rows of trees and there are many historical and religious buildings such as masques. In planning the expressways, special care must be taken to reserve these precious cultural assets.

3.3.2 Design Standards

In Iran, a unified technical standard is not stipulated as yet on the geometrical design of the roads. Although the A.A.S.H.O. Standards are operative, it is necessary to establish general standards applicable nationally as soon as possible.

Various countries have their own unified standards for geometrical designing, although there are some differences between individual countries.

We will make the expressway plan on the basis of the standards shown below, taking into account facts from various countries and the conditions of the city of Teheran.

Table 3-3-1 Design Standards for Expressways in the City

	C.B.D.Ring Expressway and Radial Expressway	Suburban Ring Expressway	Ramps
Design speed	60 km/h	100 km/h	40 km/h
Design vehicle	AASHO Standards	AASHO Standards	AASHO Standards
Minimum radius of curves	120 m	380 m	50 m
Maximum cant	10%	10%	10%
Length of transition curve	Over 50 m	Over 85 m	Over 35 m
Sight distance	Over 75 m	Over 160 m	Over 40 m
Longitudinal grade (At most)	5% (8%)	3% (6%)	7% (10%)
Ascending lane	-	To be provided when needed where longitudinal grade is over 3%	-
Radius of vertical curve Crest	Over 1,400 m	Over 6,500 m	Over 450 m
sag	Over 1,000 m	Over 3,000 m	Over 450 m
Length of vertical curve	Over 50 m	Over 85 m	Over 35 m
Length of acceleration and deceleration area	Over 160 m	Over 230 m	

3.3.3 Estimation of Traffic Volume

Unfortunately, there have not been any OD surveys conducted on vehicular traffic or personal trips so far in Teheran and therefore it is extremely difficult to make an accurate forecast of the future traffic demands. As a result, an evaluation of the feasibility of the proposed expressway project has to be made on the basis of an estimated future OD of vehicular traffic prepared on the basis of the land usage plan of the Teheran Metropolitan Area stated in Chapter 2, with the reference to the results of the surveys conducted in Japan and other countries. The aim of this estimation is to provide a means of evaluating the urban expressway projects, and therefore these figures are to be used as the basis of the project in the future, they must be re-examined on the basis of fundamental surveys such as personal trips.

Outline of the process of estimation is shown in the following chart.

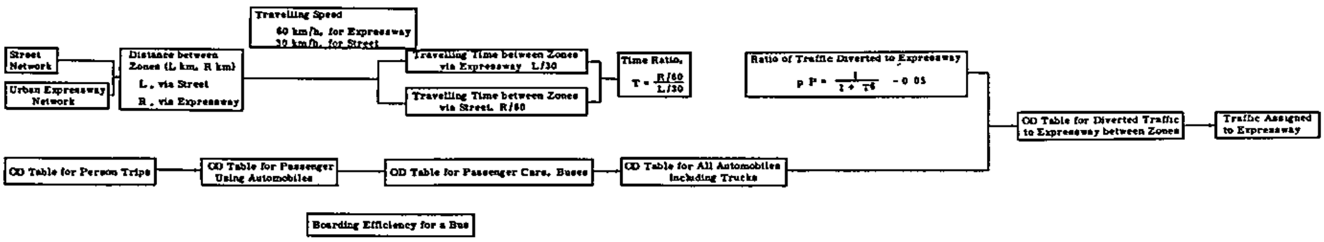


Fig. 3-3-1 Flow Chart of Traffic Assignment

The approximate traffic volume for each section of the expressway has been obtained from the flow chart shown in Fig. 3-3-1, and those results are shown in Fig. 3-3-2. Though there are some sections in which estimated traffic volume surpasses its capacity, and requires additional work in finding the appropriateness of traffic assignment on city streets and the need for improvement of city streets, the estimated traffic volume, shown in Fig. 3-3-2, is generally reasonable for the whole road network.

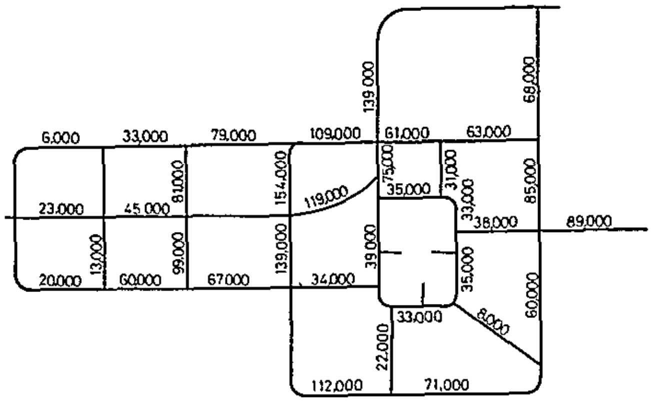


Fig. 3-3-2 Traffic volume on expressways

3.3.4 Outlines of Routes

1) C.B.D. Ring Expressway

This route should be constructed around the Central Business Districts to absorb a large volume of traffic generated in C.B.D. As there are many magnificient buildings lining the streets in this area, the acquisition of land for constructing expressways is is difficult.

As a result, we make this route, as a rule, an elevated expressway, constructed over the existing streets. In addition, since this route is to be one-way with 3-lanes, its width is such that makes this possible. Because this is a one-way operation, the layout of interchanges becomes simple requiring less land acquisitions, and it is easy to build.

It is proposed to locate this route over Boulvard, Kh. Siroos, Kh. Molavi and Kh. Simetri, but there needs to be some consideration before using Kh. Takhte-Jamshid and Ave. Shahbaz.

Although Boulvard has sufficient width to build ramps, it would be regrettable to spoil its appearance with overhead structures. On the other hand, the width of Kh. Takhte-Jamshid, being insufficient, makes it unreasonable to build overhead structures. Moreover such a structure would make it necessary to move a good number of buildings near Teheran University.

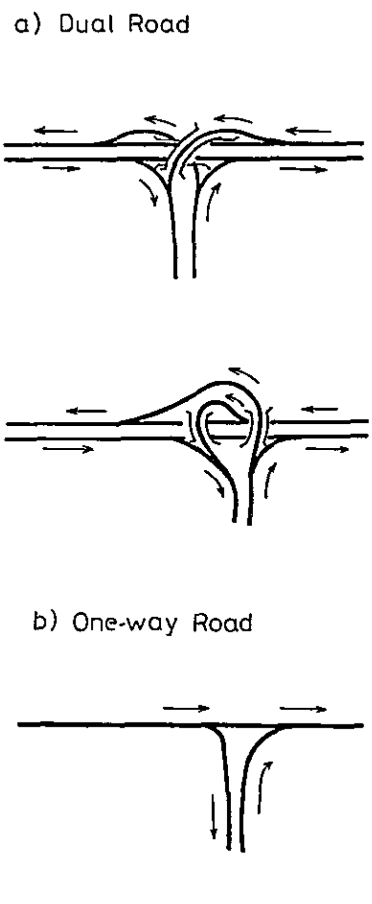


Fig. 3-3-3 Interchanges

As for Kh Siroos and Kh. Shahbaz, the former has the advantage in its accessibility to C.B.D., but the problem is that the route approaches the Diet Building and Mosque.

The location of the route should be determined after having considered the above points carafully. We think that the route proposed is preferable in view of the purpose of this route, to make the traffic in the city center flow smoothly.

The city center has been already troubled with a severe parking problem. A solution for this is, for example, to construct as all-round transport building to accommodate parked cars and a bus terminal, as a part of the urban redevelopment project, using the left over land after the government offices which are expected to move to Abbas-Abad. The Branch Roads going into the city center should be built from the C.B.D. Ring Expressway to connect directly to these facilities.

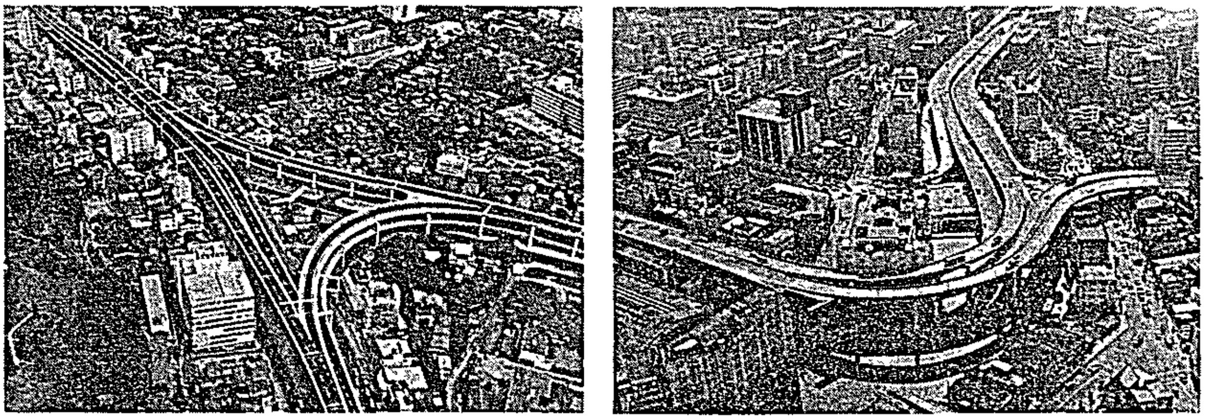


Fig. 3-3-5 Two Examples of Interchanges of Urban Expressway (Tokyo)

Fig. 3-3-4 Expressway Network in Teheran Metropolitan Area

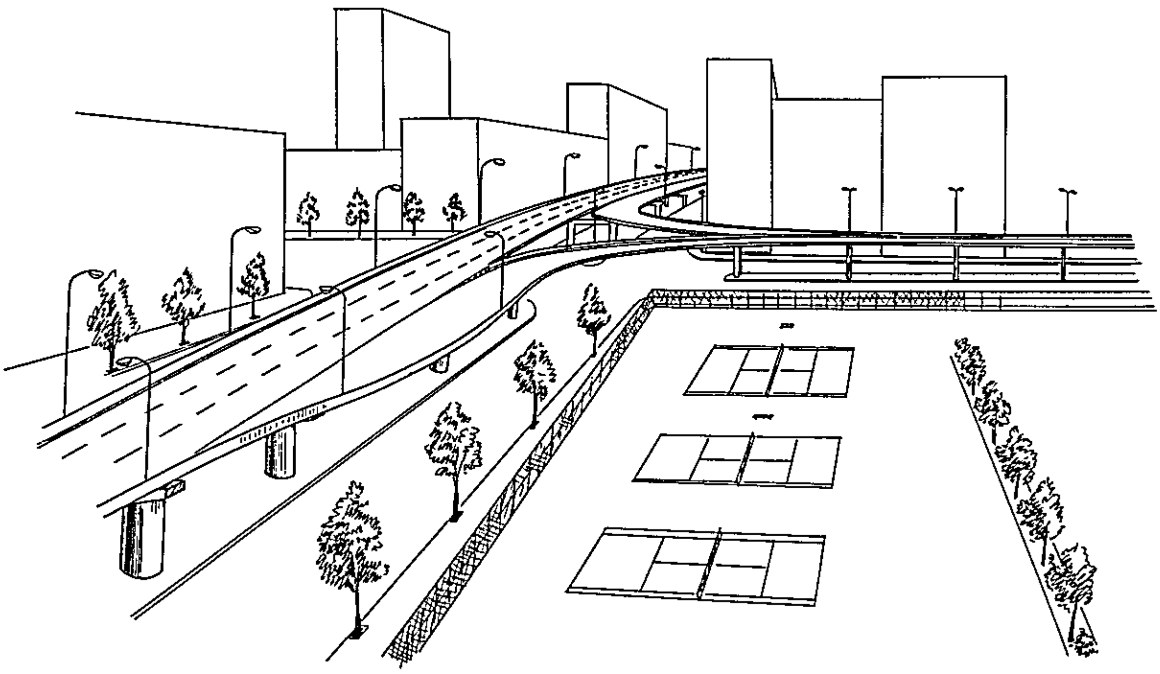


Fig. 3-3-6 Artist's View of Expressway in Teheran

2) The Suburban Ring Expressway

The Suburban Ring Expressway branches from Teheran-Karaj Super Expressway and runs in front of Mehrabad Airport, then along the border of the existing urban area and through Najaf-Abad and Farahabad east of the city. En route it hits National Highway No. 7 leading to Karaj, Saveh and Esfahan; Aramgah Road(National Highway No. 9); Rey Road leading to Rey, and Khorasan Road (National Highway No. 6) leading to Semnan and Damghan, in order to link with the inter-city highway.

This Ring Expressway further goes up to the north from Farahabad crosses Mazandaran Road and then from Narmak goes through the new government office quarter, Abbas-Abad, to link at Yousefabad with the Parkway completed recently.

This Ring Expressway is planned with 6-lane road, and except where it must pass through the existing urban area, it will be embanked as much as possible to save on cost.

Since the southern section of this Ring Expressway runs through key railway centers and national roads as aforesaid, it is desired to establish a large commodity circulation center, dealing with various commodities and goods now located dispersedly in the city. Full utilization of expressway will improve the distribution system and, at the same time, reduce traffic congestion in the city.

If a new international airport is to be constructed, a branch expressway from this Suburban Ring Expressway will be needed to serve it.

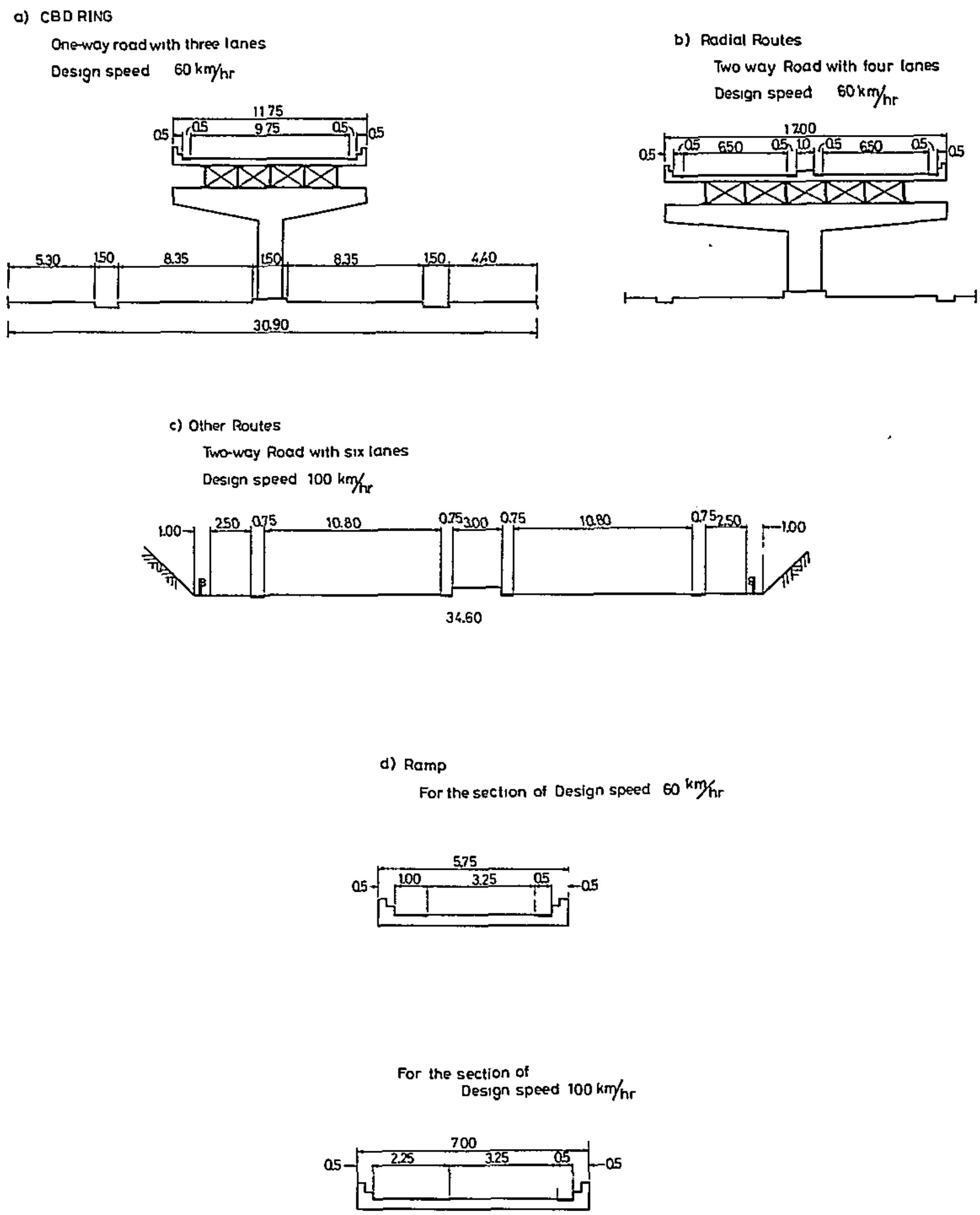


Fig. 3-3-7 Cross Sections of Expressways

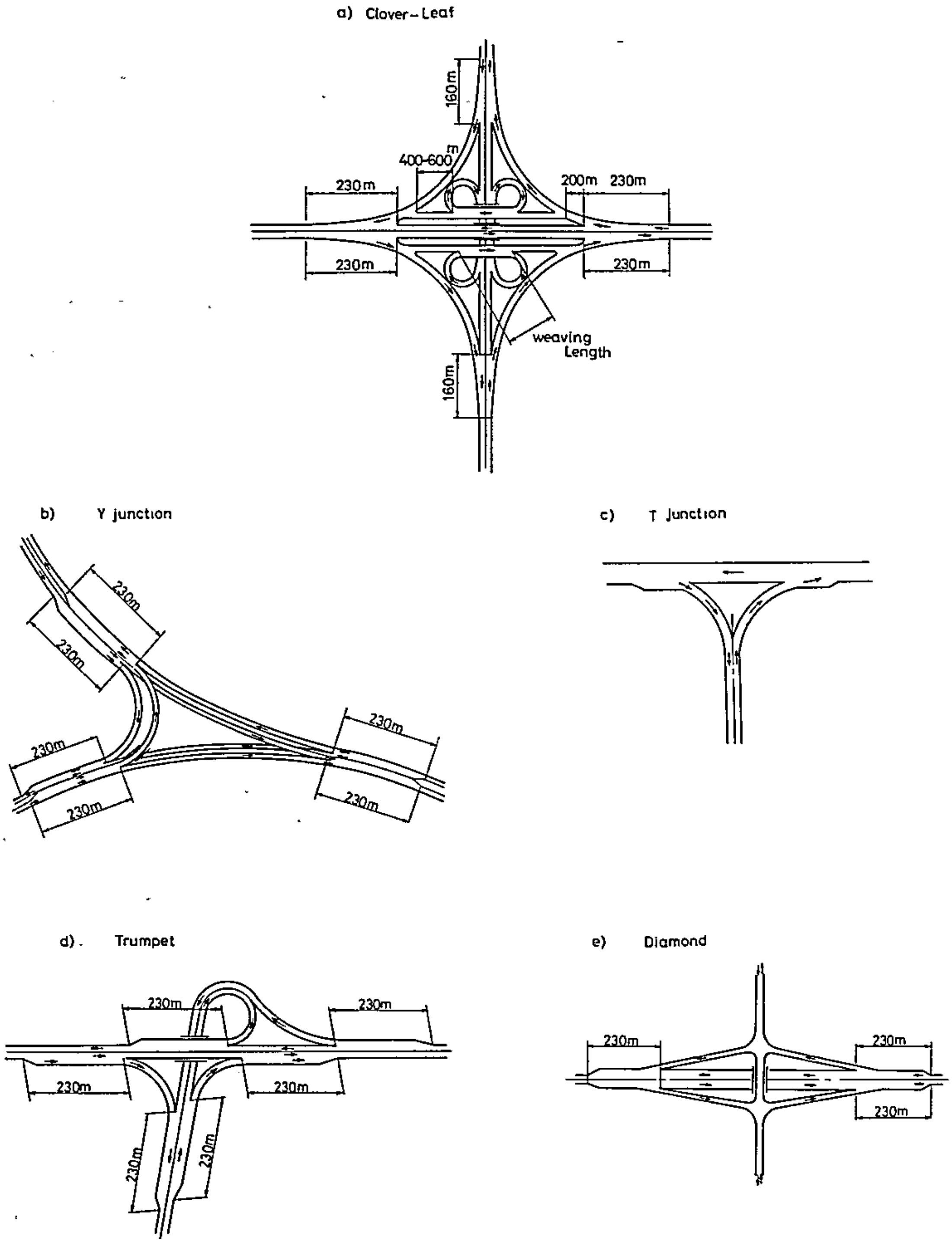


Fig. 3-3-8 Plan of Interchanges

3) Radial Expressways

The C.B.D. Ring Expressway and the Suburban Ring Expressway are to be connected by six radial expressways. These Radial Expressways having 4 lanes, will necessarily be constructed on viaducts for most of the routes, in view of the land use conditions along them.

(i) Radial Expressway No. 1

First, it needs to connect the northwestern end of the C.B.D. Ring Expressway with the Suburban Ring Expressway, passing through the vicinity of Pahlavi Hospital and linking with the Parkway which is an extension of Kennedy Ave. completed recently. This expressway connects Teheran-Karaj Super Expressway directly with the city center and, at the same time, plays an important role in carrying traffic between Tajrish and the city center along with Kh. Pahlavi and Kh. Old Shemiran, by crossing up with the above mentioned Parkway.

(ii) Radial Expressway No. 2

This route, branching from the C.B.D. Ring Expressway on Simetri Ave., runs to the west approximately along Qazvin Ave. and hits the Suburban Ring Expressway at Mehrabad. This road further connects to the West Suburban Expressway No. 3 and constitutes a route which links the area in the direction of Karaj where future growth is expected with the existing urban area.

(iii) Radial Expressway No. 3

This route, branching from the C.B.D. Ring Expressway in the southwest and crosses the railway west of the State Railway Central Station and runs through the east side of Qaleh-Morghi Airport to reach the Suburban Ring Expressway. It is intended to connect this Expressway with National Highway No. 7 going to Esfahan or with Aramgah Road. At the same time, as the site adjacent to the interchange between this Expressway and the Suburban Ring Expressway is near the railway station as well as to the area where storehouses and truck terminals are existing, it is a suitable location to establish a commodity circulation center in future. When such facilities are built in the future, this expressway will become an important route, as it connects them with the C.B.D. Ring Expressway. However, its alignment is difficult because of the many restrictive conditions in selecting its course.

(iv) Radial Expressway No. 4

This expressway branches from the C.B.D. Ring Expressway in the southeast and joins the Suburban Ring Expressway via Dolab. Its object is to serve the Khorasan Road and the Ray Road southeast of the city.

(v) Radial Expressway No. 5

This expressway runs from Teheran-Now, passing by the north side of Dowshan Tappeh Airport and through Emamiyeh to C.B.D. Ring Expressway. Its object is to link to the eastern parts of Teheran, Warmak and Teheranpars and to serve Mazandaran Road leading to Damaband. Accordingly, this route should be extended further to the east across the Suburban Ring Expressway. As there is a plan to construct a rapid-transit railway beneath this route, the planning and the construction time should be coordinated with such a plan.

(vi) Radial Expressway No. 6

This road extends from Abbas-Abad straight from south to north to reach the C.B.D. Ring Expressway. It will become an important connecting route between the existing urban area and the government office quarter which is to be set up at Abbas-Abad in future,

4) West Suberban Expressways

Two 6-lane expressways will be laid on the south and north sides of Teheran-Karaj Super Highway. The West Suburban Expressway No. 1 laid on the side near the mountain will be connected to the residential districts which will be developed in the future, and join to Suburban Ring Expressway at Yousefabad in the east. Since its main object is to link the residential districts with each other, many more access rampways will be provided as compared with other expressways.

West Suburban Expressway No. 3 (No. 2 is existing Teheran-Karaj Super Expressway) in the southern area is planned as an arterial road to serve the business and industrial districts of which future development is expected. These three expressways running from east to west will be connected to three expressways (West Suburban Expressway No. 4, 5 and 6) extending from north to south. Their courses should be located in accordance with the plan of the new sub-centers with a population of 500, 000.

As these West Suburban Expressways run through barely urbanized areas, it is desirable to determine the route location plan as soon as possible.

5) Tajrish Expressway

This is an auxiliary route of The Suburban Ring Expressway forming.a half ring; it branches from the interchange between the Suburban Ring Expressway and the West Suburban Expressway No. 1 at Yousefabad and uses the route of the existing Parkway to connect to Pahlavi Ave.; after which it runs to Chizar through the planned extension of the Parkway- of which the route has been determined already - to join with the road leading to Lashgarak and Shemshak (This route is expected to be a link to the Caspian Sea), then it runs down to the south to connect to the Suburban Ring Expressway again at Narmak. As stated above, this road, besides linking with the future arterial roads leading to the Caspian Sea, serves the area which includes the high class residential district, hotels and university, and car drivers going to enjoy a cool evening in summer.

3.4 Project Planning

3.4.1 Estimated Construction Cost

Estimated construction cost required for the completion of these expressways is shown in Table 3-4-1.

Since there has been no experience with large scale PC structures or steel structures in Iran such as planned in this project, the cost estimate using the standard price in Iran was extremely difficult. Cost estimation was made using prices in Japan as a standard tentatively and revisions were made based on the data obtained in Iran on usages and the unit cost of material and contingencies.

Unit price used for cost estimation: (1 Iranian Rial = 5 Japanese Yen)

(1) Superstructure

P.C. simple composite beam girder (cast-in-place);	12,000 Rials/m^2
P.C. simple composite beam girder (made in yard);	11,000 Rials/m^2
Metal simple composite beam girder;	6,200 Rials/m^2
Metal simple box girder;	11,000 Rials/m^2

(2) Substructure

For 1-3 lane bridge

Reinforced T shape pier, footing foundation; (metal for Superstructure)	5,600 Rials/m^2
Reinforced T shape pier, footing foundation; (P.C. for Superstructure)	6,800 Rials/m^2
Metal T shape pier, footing foundation; (metal for Superstructure)	6,000 Rials/m^2
Metal T shape pier, footing foundation; (P.C. for Superstructure)	7,400 Rials/m^2

For 4 lane bridge

P.C. Ⅱ shape pier, footing foundation; (metal for Superstructure)	5,600 Rials/m^2
P.C. Ⅱ shape pier, footing foundation; (P.C. for Superstructure)	7,200 Rials/m^2

For 6 lane bridge

P.C. Ⅲ shape pier, footing foundation; (metal for Superstructure)	7,800 Rials/m^2
P.C. Ⅲ shape pier, footing foundation; (P.C. for Superstructure)	10,000 Rials/m^2

(3) Flooring;	3,600 Rials/m^2
(4) Pavement;	800 Rials/m^2

(5) Earth Work;

Cutting;	100 Rials/m^2
Banking;	100 Rials/m^2

Note: The unit price used for the steel structure is the unit price of fabrication in Japan plus the cost of erection at the site, and does not include freight or custom duties. The unit price used for the P.C. structure, meanwhile, is the local unit price.

Estimation of construction cost for each route with the use of these unit prices is shown in Table 3-4-1.

Table 3-4-1 Expressway Construction Cost

Route	Elevated section		Bank or Cut section		Flat land section		Total	
	Total length (km)	Construction cost (million Rials)	Total length (km)	Construction cost (million Rials)	Total length (km)	Construction cost (million Rials)	Total length (km)	Construction cost (million Rials)
C.B.D. Ring Expressway	16.5	3,100	-	-	-	-	16.5	3,100
Branch Roads	3.0	680	-	-	-	-	3.0	680
Radial Expressway No. 1	3.5	970	-	-	-	-	3.5	970
" " No. 2	5.0	1,370	-	-	-	-	5.0	1,370
" " No. 3	4.5	1,310	-	-	-	-	4.5	1,310
" " No. 4	5.0	1,370	-	-	-	-	5.0	1,370
" " No. 5	11.0	3,020	-	-	-	-	11.0	3,020
" " No. 6	3.3	970	-	-	-	-	3.3	970
Branch of Radial Expressway No. 5	11.4	8,300	0.7	40	66.9	160	18.0	8,300
Suburban Expressway	21.7	15,900	1.9	190	24.3	440	51.7	15,900
Tajrish Expressway							6.5	170
West Suburban Expressway No. 1	-	-	5.9	320	12.2	320	12.2	640
" " " No. 2 (existing but widened)	-	-	3.5	20	13.1	70	13.1	90
" " " No. 3	-	-	-	-	22.1	590	22.1	590
" " " No. 4	-	-	-	-	3.0	80	3.0	80
" " " No. 5	-	-	-	-	8.5	220	8.5	220
" " " N0. 6	-	-	-	-	5.0	130	5.0	130
Inter-changes between No. 1, 2, 3 Branches and C.B.D. Ring Expressway	3	210					3	210
Three-way interchange between Radial Expressway and C.B.D. Ring Expressway	6	520					6	520
Regular three-way interchange	5	290	6	70			11	360
Regular four-way inter-change for regular section	6	7,260	1	200			7	7,460
Intermediate access road	120	1,600	60	270			180	1,870
Crossing of roadway and horizontal section with city streets			60	200			60	200
Total								50,440 million Rials

3.4.2 Economic Benefits

Such huge investment must be justified by its economic benefits. It is recognized that the economic benefits are generated in two ways, direct and indirect; the former being generated directly from usage of the road. Among them, such as the reduction in travelling cost is measurable in quantity, but such as reduction in driver's fatigue and increase in comfort are not yet quantified.

Economic benefits of road investment

- Direct benefits;
  1. Reduction in travelling cost
  2. Decrease in travel time
  3. Reduction in road maintenance cost
  4. Reduction in packing and in baling cost
  5. Decrease in traffic accidents on road
  6. Increase in comfort
     Decrease in fatigue
- Indirect benefits;
  1. Increase in land usage along road
  2. Rationalization of production and transportation planning
  3. Dispersive effect of industrial areas
  4. Development of resources
  5. Dispersion of urban population
  6. Rationalization of commodity distribution economies
  7. Expansion of market area

It cannot be expected that all of these benefits are derived from any one urban expressway constructed in a great city such as Teheran, but rather from the roads as a whole.

(1) Reduction in Travelling Cost

The travelling cost is reduced as a result of the reduction in the length of the road, and the improvement of the road surface, and decrease in tire wear, damage of vehicle, depreciation and personnel expenses.

The amount of reduction is found in the following way.

$$\Delta C = Gc - Hc$$

$$Sc = \sum_{i=1}^{m} \sum_{j=1}^{n} Xij \; \Delta Cij$$

ΔC - reduction in travelling cost per vehicle

Gc - travelling cost on existing road

Hc - travelling cost on newly constructed road

Sc - total amount of reduction in travelling cost

Xij - traffic volume of car type of i, which are diverted to j section of newly constructed road from existing road

ΔCij - amount of reduction in travelling cost for car type i diverted to j section of newly constructed road from existing road

The travelling cost as analized in relation to the general streets and the urban expressway in Japan are as shown in the following tables.

Table 3-4-2 Travelling Cost of Vehicles Operating on General Streets and Urban Expressways

General roadways (unit: Rials/km)

	Commercial vehicle				Private car		
	Passenger Car	Bus	Ordinary truck	Small truck	Passen-ger Car	Light 4-wheeled car	Bicycle
Fuel	1.10	1.67	1.65	1.50	1.25	0.61	0.30
Lubricant	0.05	0.17	0.15	0.07	0.11	0.09	0.05
Tyre & tube	0.07	0.21	0.22	0.09	0.07	0.05	0.04
Repair of vehicle	0.61	1.58	1.16	0.78	0.94	0.48	0.17
Depreciation of vehicle	0.74	1.80	2.00	1.24	1.54	0.94	0.54
Total	2.57	5.43	5.18	3.68	3.91	2.17	1.10

(unit: Rials/km)

Urban Expressways

	Commercial vehicle					Private car	
	Passenger car	Bus	Ordinary truck	Small truck	passen-ger Car	Light 4-wheeled car	Bicycle
Fuel	0.83	1.00	1.04	1.02	0.95	0.47	0.25
Lubricant	0.04	0.10	0.10	0.03	0.08	0.07	0.05
Tyre & tube	0.70	0.21	0.21	0.09	0.07	0.05	0.04
Repair of vehicle	0.50	1.10	0.79	0.55	0.77	0.39	0.13
Depreciation of vehicle	0.74	1.80	2.00	1.24	1.54	0.94	0.54
Total	2.18	4.21	4.14	2.95	3.41	1.92	1.01

(2) Decrease in Travel Time

The travel time decreases due to reduction in distance and increase in travelling speed provided, as a result of new construction of roads, with a consequential increase in the number of trips and an expansion in the travelling range.

$$\Delta t = G_T - H_T$$

$$S_T = \sum_{i=1}^{m} \sum_{j=1}^{n} X_{ij} \, \Delta t_{ij} \cdot C_i$$

Δt - reduction in transport time per vehicle

G_T - travelling time on existing road

H_T - travelling time on newly constructed road

S_T - total amount of benefit as reduction in transport time

X_{ij} - traffic volume diverted to j section of expressway from existing road

Δt_{ij} - reduction in transport time for car type i diverted to j section of newly constructed road from existing road

C_i - amount of time benefit for a car type i

Table 3-4-3 Tentative Calculation of Amount of Time Benefit Enjoyed by Vehicles and Goods or Passengers, in Japan

(unit: Rials/vehicle-minute)

Class of vehicle	Benefit for vehicles	Benefit for goods or passengers	Total
Ordinary truck	0.35	0.83	1.18
Small truck	0.19	0.45	0.64
Bus	0.26	5.52	5.78
Passenger car			2.00

(3) Reduction in road maintenance cost

(4) Reduction in packing and baling cost

(5) Decrease in traffic accidents on the road

(6) Increase in comfort; Decrease in fatigue

The economic benefits from the Teheran expressway network a among those listed above are as follows:

o Reduction in Travelling Cost

On the assumption that the total travelling vehicle•km on all new expressways in Teheran amount to 900,000 vehicle•km and that traffic is composed of 85% passenger cars, 10% trucks and 5% buses, the annual reduction in the travelling cost calculated on the basis of the previously mentioned value is expected to reach 19,000 million Rials.

o Reduction of Travelling Time

The time saved by travelling on the expressway instead of travelling on existing roads is expected to amount to about 10 minutes on the average. Assuming that the number of vehicles utilizing the expressway daily is about 1.5 million, the annual time benefit will amount to 8,600 million Rials.

These figures represent the total benefit derived from the estimated traffic volume upon the completed networks and therefore, can not be expected during the construction period. In the long run, however, this project will bring sufficient economic benefits and be worth 50,000 million Rial investment.

3.4.3 Administrative and Financial Problems

a. Toll Road System

For the Teheran expressway project, financing the entire projects by general income such as tax revenue alone will be a considerable burden. It is worthy of full review, therefore, to positively induce private capitals and loans from foreign countries to accelerate the construction of the expressways. As the majority of economic benefits derived from the urban expressway are direct benefits such as the reduction in travelling time and travelling cost, any imposition in repayment would be worthwhile considering benefits derived. In the United States of America, the toll road system is actively utilized for local roads such as the Inter-State Highways. Examples of the toll road system for an urban expressway network are seen in Tokyo, Osaka and Kobe of Japan. In this report, the Metropolitan Expressway Public Corporation which is responsible for the construction of urban expressways in Tokyo will be taken as an example.

b. Construction of Toll Urban Expressways in Tokyo

Because of a lack of social capital during economic rehabilitation after World War II, there was a lag in road construction and the construction of roads became a pressing need and as a result, the toll road system become an asset. In 1952 thr Law Concerning Special Measures for Improvement of Road was enacted. By this law, the central or local governments were empowered to obtain government funds for the construction of roads, to collect toll charges for the redemption of loans and to open the road to the public free of charge after redemption was completed.

With the adoption of this toll road system, investment of huge amounts of capital in a project in a short period of time was possible and the construction of roads were considerably accelerated. As a result, the Japan Highway Corporation was established in 1956 for the purpose of inducing private capitals as funds for the construction of roads in the local area. Beginning with the Second 5-Year Road Project (from 1956), emphasis was placed on the construction of state and urban expressways, which require construction standards higher than those for ordinary roads. Under this project the Tokyo Expressway Public Corporation was established in Tokyo area in 1959 and the Hanshin Expressway Public Corporation was established in Osaka in 1962, for the purpose of constructing urban expressways.

3.4.4 Priority in the Start of Construction Work

As it is almost impossible to start construction work of all planned road networks at the same time, the work must begin from the section that can be opened immediately, corresponding to the expansion of the city area, increase in the traffic volume and related projects such as urban renewal work.

The present bottleneck in the traffic in Teheran is in the commercial business district in the heart of the city, between Bazar and Shahreza. To alleviate traffic congestion in this district, C.B.D. Ring Expressway and Radial Route No. 1 which connects C.B.D. Ring Expressway to Kennedy Ave. must be completed first in conjunction with the implementation of emergency measures on traffic control, as suggested in Chapter 5. At the same time, present Teheran - Karaj Super Expressway should be extended to cross the Parkway. With the completion of these routes, smooth traffic flow in the major directions from the center of Teheran to Tajrish , Karaj, Qazvin may be realized.

The branch route from the C.B.D. Ring Expressway to the center of the city should be planned to match the timing of urban renewal projects inducing the construction of terminal buildings.

Construction of the southern portion of the suburban Ring Expressway must be coordinated with the timing of reassignment of warehouses into the commodity circulation center, or the timing of construction of a new international airport.

The construction of Radial Route No. 9 and the northern portion of the Suburban Ring Expressway should also be coordinated with the plan for transferring government offices to Abbas-Abad.

Construction of Tajrish route should be decided in relation with the traffic conditions on the trunk roads running from north to south, such as the recently completed Parkway, Pahlavi Ave. and Old Shemiran Ave.

For other West Suburban Expressways except for the existing Teheran - Karaj Super Expressway, the timing of construction should be determined in connection with the progress of the subcenter projects in these areas.

CHAPTER 4 RAILWAY AND MONORAIL

4.1 Basic Requirements for Route Selection

In this section a study will be made on the subway which is considered suitable for Teheran City.

The most important element in selecting a route for an urban railway is to make a proper forecast of the future of the city after a fully studying and thoroughly understanding the existing conditions of the city. For a city like Teheran in particular, for which the concept of high speed mass transportation (for the urban area) is being formulated for the first time, it is important to plan a balanced underground railway network by taking into consideration the future structure of the urban area.

For this purpose, the following conditions must be considered as a basic requirement.

(1) Each line must pass through the center of the city.

(2) The proposed lines must contribute to the easement of congested surface traffic.

(3) The proposed lines must pass through densely populated areas or areas where dense population is expected in the future.

(4) There must be room left for future extensions of the line to match the development of the suburban area, and in view of the huge amount of construction costs required for an underground structure, the lines in the suburban areas; should be brought to the surface as soon as is possible.

(5) The alignment of the lines should be determined so as to conform with the city road projects as far as possible.

(6) The alignment of the lines should be such that they will enable passengers to go in any direction with the least number of transfers (one transfer, if possible).

(7) Consideration must be given to the walking distance of passengers, and the distance between each station should be within the range of 700 m to 1,000 m in the downtown area and from 1,500 m to 2,000 m in the suburban areas.

(8) Efforts should be made to curtail construction costs and time by avoiding the use of privately owned land.

(9) Full consideration should be given to securing land space for car sheds and maintenance shops.

In the above principles are to be applied to Teheran City, the following detailed requirements may be supposed.

Item (1)

The present structure of Teheran City is the so-called single core type. In other words, the office district, shopping area, amusement center and other activities are concentrated mainly in the center of the city, covering a total area of about 8 km^2, while the city is expanding toward the suburban areas with the center of the city as the axis of expansion. The city of Teheran is expected to expand further to the west in the future because of topographical limitations, and city plans are also based on this consideration. Therefore, the proposed route which is aimed at connecting each block of the sub-metropolitan area planned for the west side of the city should pass through the center of the present city and the new government office district planned for Abbas-Abad.

Item (2)

Leaving aside private cars and taxis, the existing bus routes with large number of buses in operation are faced with a steady demand for transportation all along the route. Therefore, these bus routes should be included in the plan so that the demand may be absorbed by the subway. Easement of surface traffic congestion by such means is important.

Item (3)

Since there is a large demand for transportation between the residential areas and the center of the city, it is advisable that the lines be routed through the areas with a large night population and the areas for which housing projects are being planned.

Item (4)

In view of the huge investment required for the construction of a subway, extension of the lines to proposed future city areas under the current project is not economical. Therefore, the current plan should aim only at the existing city areas, and the possibility of line extension should be left for the future, because there are often cases in which the extension of lines becomes necessary. For this reason, consideration must be given to the procurement of land as well as to the plan for the future extension of the line. Efforts should also be made to curtail construction costs by keeping the length of the underground sections as short as possible and limiting them only to the places where no other m eans are available, and by building surface lines as much as possible.

Item (5)

This paragraph is also connected with items (2) and (8). In the case of projected lines in particular, the road projects should precede the subway projects and it is desirable that the roads have a width commensurate with the design of the station.

Item (6)

In railway transportation it is very important to ensure the convenience of the passengers by reducing as much as possible the frequency of the transfers needed to reach one's destination. Transfer to another train is not only a loss of time for passengers but is very inconvenient because passengers are required to use stairways. For this reason, the line network must be planned so carefully that passengers are required to make only one transfer, at the most, and that detours caused by transfers are avoided as much as possible.

Item (7)

In planning a subway, it is most important to know how much walking distance is permissible between residential areas and the nearest stations and between the station and the destination of the passenger in the downtown area. It is advisable in general that the station be located within a range of a 10 minute walk or 700 meters. However, because of the radial expansion of the railway network, the distance between each line becomes greater in proportion to the increase in the distance from the center of the city, and, accordingly, the above distance will have to be extended somewhat. Therefore, the appropriate walking distance should be 1 km in the suburban areas and 500 meters in the downtown area, and the distance between each station should be 1.5 km to 2 km in the suburban areas and 700 m to 1,000 m in the downtown area.

Item (8)

With the progress of urbanization in the area, the price of land generally tends to skyrocket and land often becomes the object of investment and speculation. In the downtown area, particularly, the cost of land often threatens the overall construction costs, and problems arising from the acquisition of land sometimes cause a delay in the construction work. It is economical therefore, to plan for the utilization of existing street, roads and parks for the underground portion of the line.

Item (9)

Car sheds and maintenance shops also require a considerable expense of land. For this purpose, land must be acquired in the suburbs of the city, but in selecting the site, careful consideration must be given to maintaining the balance between this project and the city planning project of the proposed site.

4.2 Rapid Transit Railway Network Plan

The first and primary object of the subway is the alleviation of the congestion of surface traffic. When ways of easing the traffic confusion in the streets were sought, as the volume of traffic grew, the grade separation of surface traffic was first contemplated, followed by elevated railways and finally the subway. These plans have all been put into practice in that order.

These means of transportation run in all directions through the main streets in the center of the city connecting the key points of the city area, and have come to play an important role as a means of transportation for city people. However, with the pressing need for commuter transport facilities as a result of the gradual expansion of the residential area to the outskirts of the city area and further to the suburbs following the growth of the Metropolis, the construction of a railway which provides mass transportation within a short period of time has been contemplated, for the purpose of easing surface traffic.

For Teheran city, the easement of surface traffic congestion must also be given top priority. Alleviation of road traffic at such points as Shahreza Street, Shah Street, Pahlavi Street, and Ferdowsi Street, all of which lead to the center of the city where government offices, business firms and bazars are located and which are already in a state of confusion, must be given first consideration. However, with this measure alone, investment will fall behind the increase in traffic and effective traffic control can not be expected. The planning of a railway network must be carried out in line with future city planning projects by linking it with land use and road projects. As the city planning project for Teheran city places emphasis on the expansion to the west of the city, the railway network plan should be worked out in line with this project.

In Teheran the pace of economic development is very high and the concentration of population in the city area is increasing very rapidly. The lag in public facilities, particularly transport facilities, is very conspicuous and there is a need for immediate steps to improve transportation facilities. However, the construction of roads and railways not only requires a vast amount of investment but takes a long period of time. Therefore, the planning of such projects requires first a careful study of the feasibility of any project.

In determining the railway network, it would be economical to consider the Iranian State Railways, after their improvement as part of the extension of the subway.

According to the future plan of Teheran City, several subcenters are to be created in the area west of the city and a new government office district is to be provided in Abbas-Abad. However, the present downtown area of the city will still be the center of the city in the future and therefore it would be appropriate to plan the future railway network with emphasis placed on the existing center area of the city. Based on this concept, the following lines are recommended.

No. 1 Line

This line runs through the State Railways at the Central Station to handle passengers from the State Railways, extends to the north along Khayyam street, crosses No. 3 Line which runs along Sepah Street and No. 2 Line which runs along Shah Street, extends further to the north and crosses No. 4 Line at Abbas-Abad where a new government office district is being planned, and then heads for Tajrish. In the future, this line is expected to be extended to Evin which includes a school zone where universities are located. This line connects with each of the projected lines and it not only links the government office district with the business district by running through the center of the city from north to south but is the principal connecting link with the proposed new government office district and developing area further north, and links up with Tajrish where a high class residential area is located.

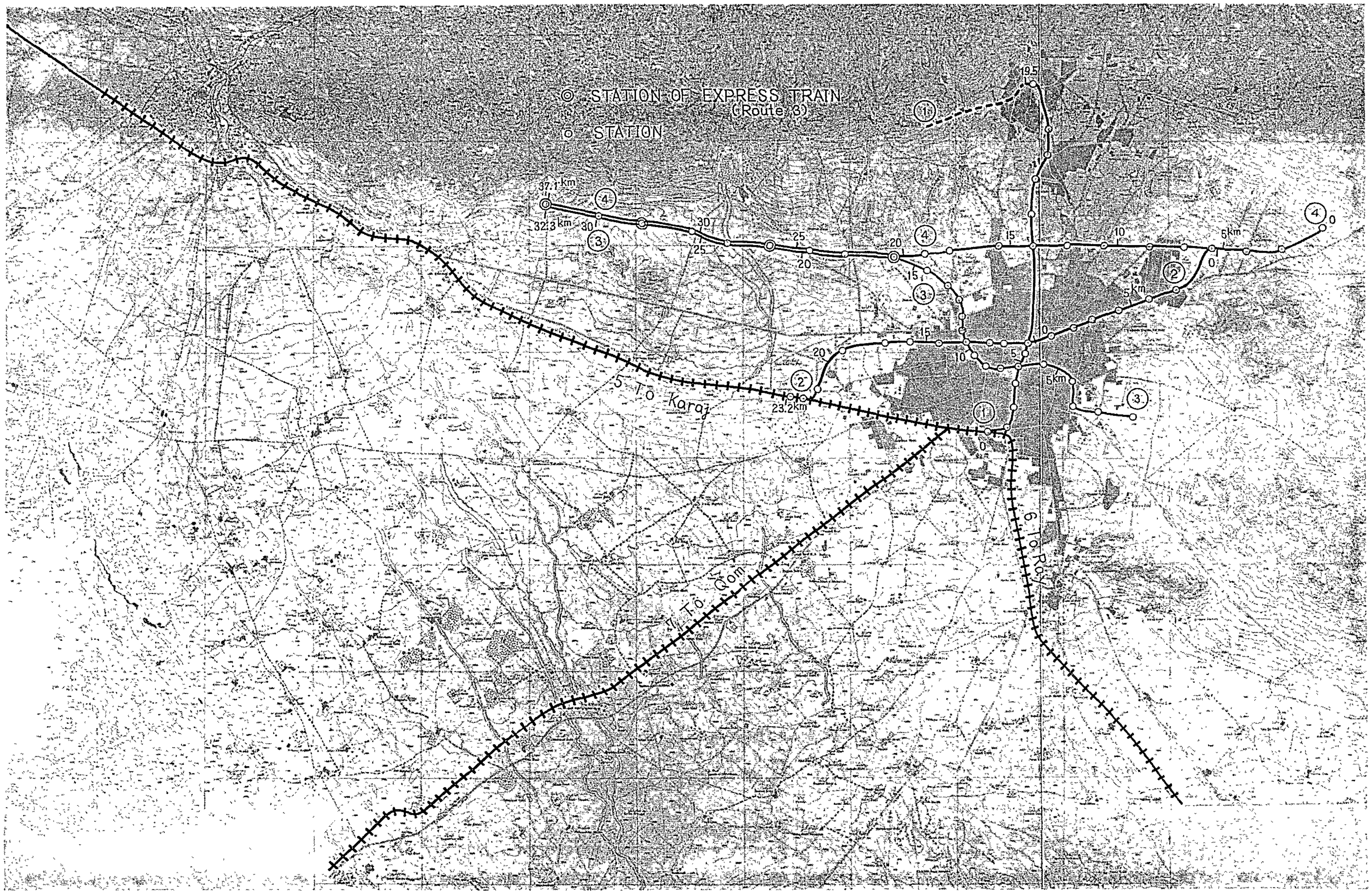


Fig. 4-2-1 Subway networks in Teheran

Fig. 4-2-2 Profile of No. 1 line

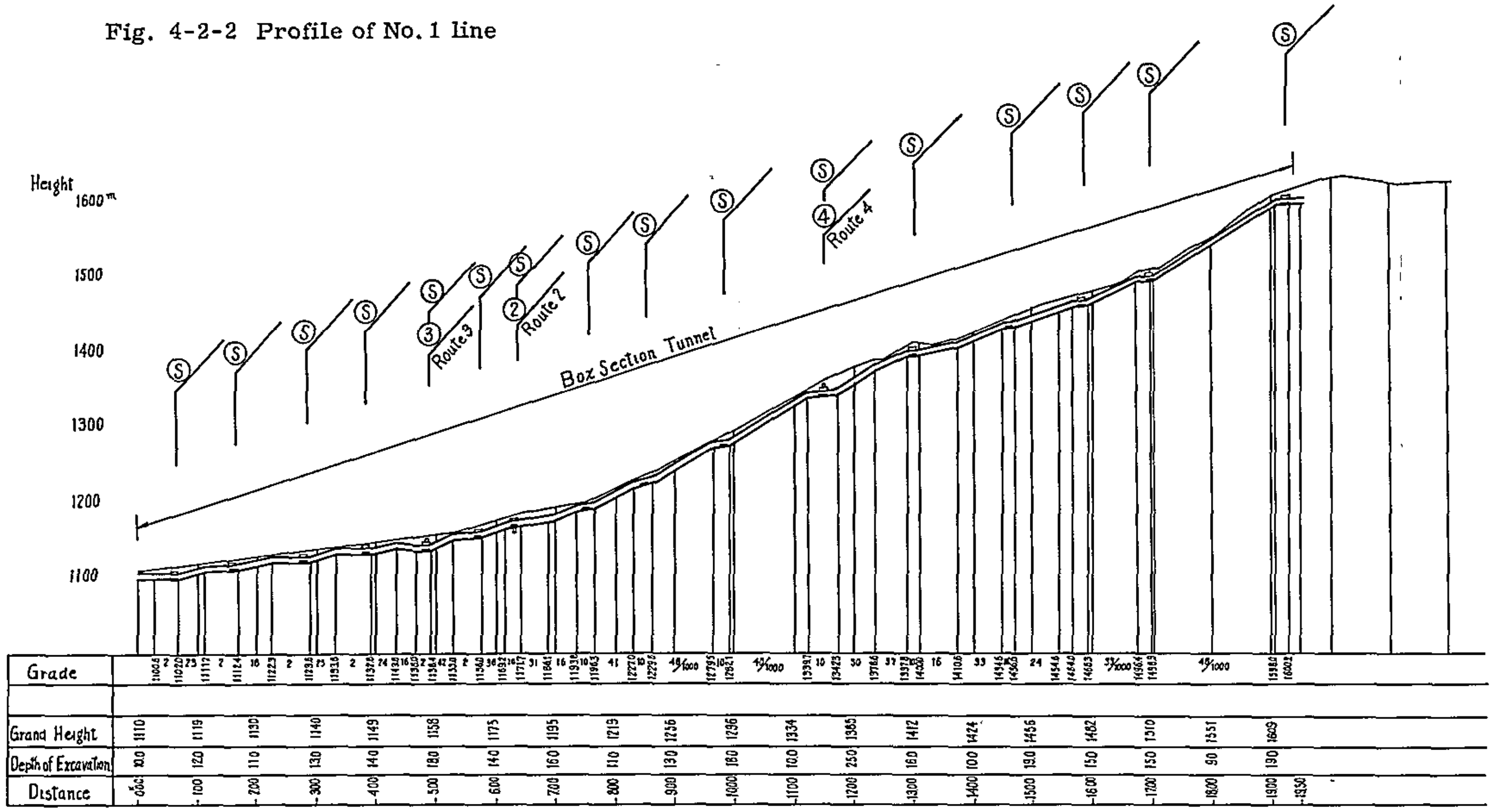


Fig. 4-2-3 Profile of No. 2 line

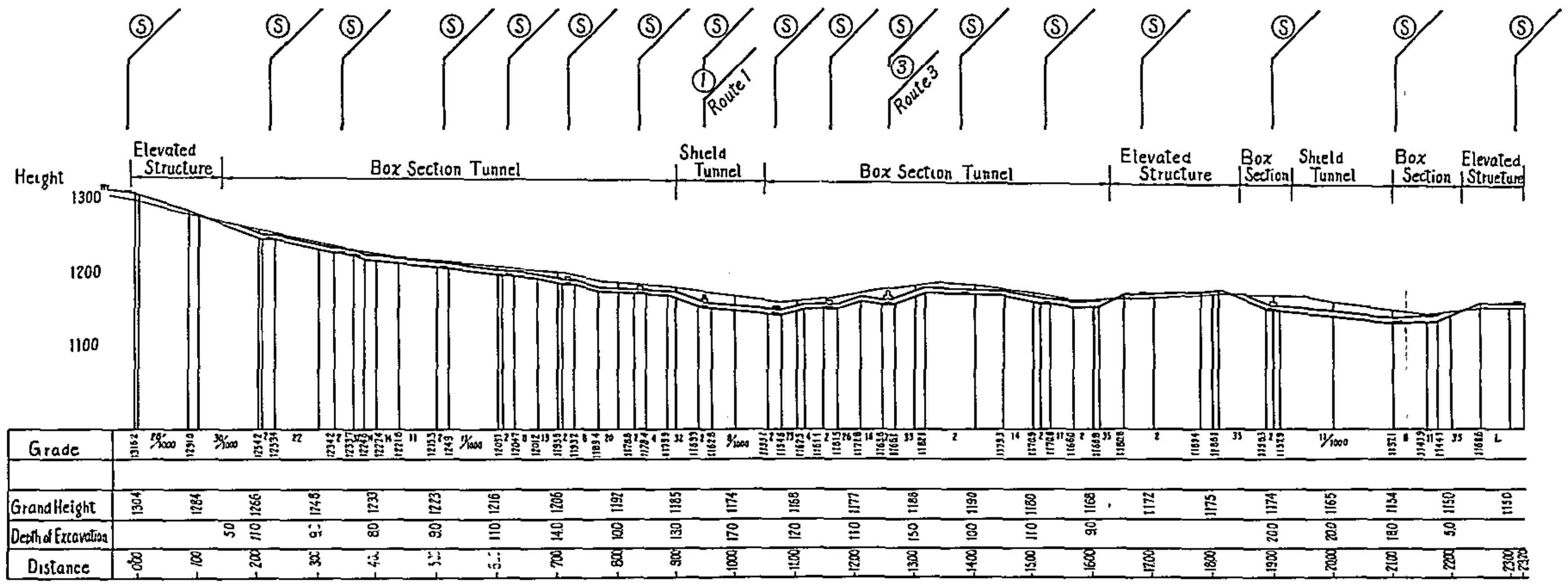


Fig. 4-2-4 Profile of No. 3 line

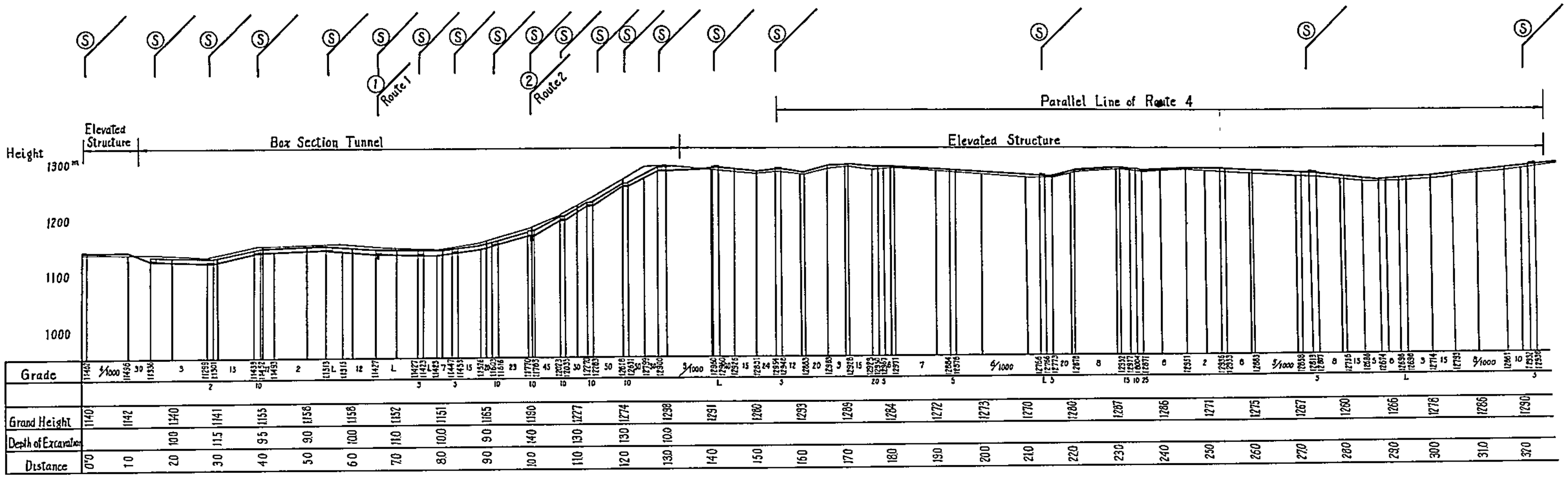
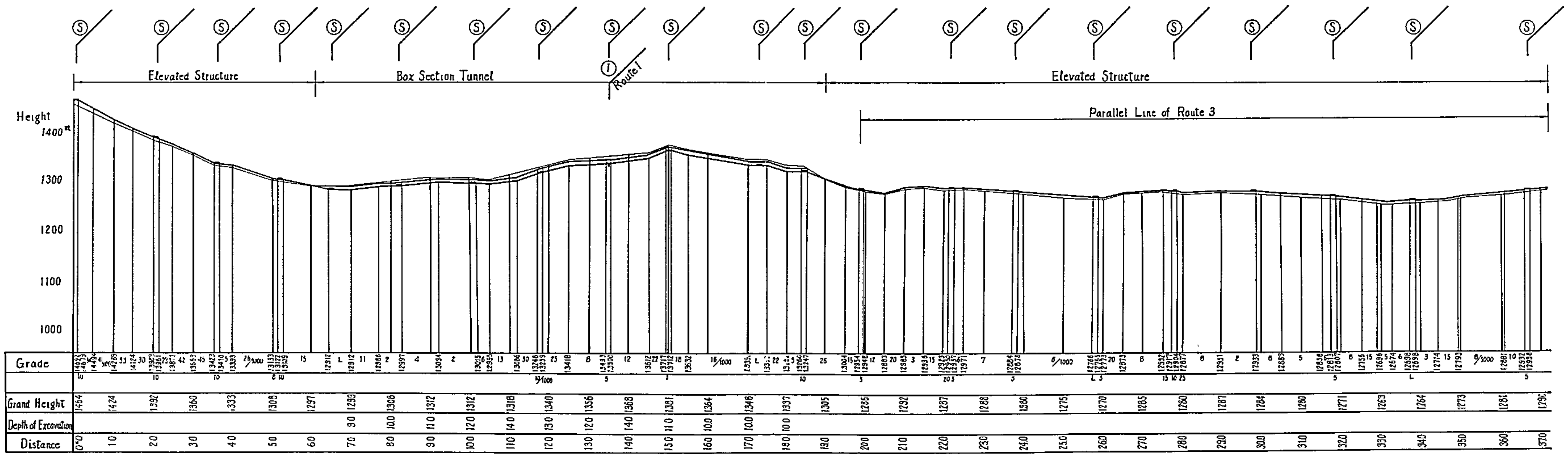


Fig. 4-2-5 Profile of No. 4 line



No. 2 Line

A new State Railway station is to be constructed at a point south of the international airport, from which the line is to run under the airport, proceed east at a point south of Eisenhower Street, enter Shah Street, and then head toward the east to link with the No. 4 Line at the proposed new city area planned for the west of Teheran Pars. Both Eisenhower and Shahreza Streets are main roads which run through Teheran city from east to west and the alleviation of traffic congestion in these streets is most urgent.

As a means of easing traffic congestion, a road with two level crossings is being planned for this route as previously discussed in the Chapter on the road project. Consequently, the construction of a railway line on this route will be extremely difficult unless it is done along with the construction of the road. Also, in view of the restriction on the design of the station that states it must conform with the road project, it is advisable to avoid this road in planning a railway line. Though the definite location of the proposed international airport is not known, it is advisable to plan a future extension of this line depending on the location of the airport.

No. 3 Line and No. 4 Line

According to the city plan of Teheran City, several satellite cities, each having a population of around 500,000, are to be created in the western suburbs. These lines are aimed at linking the centers of these new cities with the heart of Teheran City. If the city plan project is carried out as planned, these lines are expected to accommodate the largest number of passengers. This is one of the reasons for planning two lines for this region. Another reason is the great distance between each key point (5k - 6k) and the fact that the distance from the center of Teheran City is 25 km and operation of express trains along with local trains is necessary to shorten commuting time and to accomplish effective land utilization.

This line branches off into two lines near Daryane-now. One line runs down south along Amirabad Street then heads east along Sepah Street and reaches the proposed city area planned for Soleymaniyeh southeast of Teheran City. The other line runs along Abbas-Abad and heads east to reach Teheran Pars.

The total length of the four lines, No. 1 line through No. 4 line, is 112.1 km as shown in the Table below.

In selecting the route an effort was made to limit the underground structure, which requires high construction costs, to a minimum, except for the section for which the underground structure is unavoidable, and to bring the line to the surface as fast as possible. The route was classified into structural types as shown in Figs. 4-2-2 and 4-2-5. The surface portion of the route was designed to be on elevated structure in consideration of the future development of the city.

Table 4-2-1 Length of Each Line

Unit km

Structure \ Route No.		No. 1 Line	No. 2 Line	No. 3 Line	No. 4 Line	Total Length
Underground structure	Box Tunnel	19.5	15.4	12.0	12.7	59.6
	Shield Tunnel	-	3.2			3.2
Elevated Structure		-	4.6	20.3	24.4	49.3
Total length		19.5	23.2	32.3	37.1	112.1

4.3 Estimated Volume of Railway Transport

As the City Planning Project described in Chapter 2, the total number of independent trips will be 26.4 million, comprising pedestrians, bus and car passengers, and railway passengers. These city road construction and expansion projects are being carried out vigorously and most of these projects are expected to be completed in a few years. Though the construction of new road networks and expressways or grade separations of crossings have been proposed as described in Chapter 3 (Road Project), the construction or improvement of the road in the city area has its own limit, and there is a need for providing administrative guidance for encouraging the shift of automobile passengers to mass transport facilities such as subways and buses.

To use mass transport facilities to commute to the downtown area, passengers are required to walk or take a bus to the subway station or drive themselves or have their family drive them to the subway station (Park and Ride System or Kiss and Ride System prevalent in the U.S.A.), In this way, the use of private cars for commuting between the suburbs and the downtown area during the rush hour will be minimized.

As for the estimated railway transport capacity, the total number of trips by railway is estimated at 4.15 million daily on the basis of the calculations in Chapter 2.

The breakdown of this figure shows that the route going toward the west, running through Amir Abad and Hasen Abad in the west and north of the proposed Olympic Stadium and then reaching the center of each proposed city area has the largest number with 1.1 million trips. Next the route towards the north linking Abass Abad with Tajrish has 820,000 trips, while the route going toward the east reaching Teheran-pars has 550,000 trips. The route going southeast heading for Soleymaniyen and Dolab has 480,000 trips and the route going south along the State Railway including Rey has 380,000 trips. The number of trips in the downtown area of the city is estimated at 800,000.

The estimated number of passengers transported daily by each subway line and the improved portion of the State Railways is shown below.

Subways	No. 1 Line	700,000
	No. 2 Line	562,000
	No. 3 Line	1261,000
	No. 4 Line	912,000
Improved portion of the present State Railways	5 For Karaji	315,000
	6 For Rey	310,000
	7 For Qom	81,000
	Total:	4,141,000 passengers

The number of passengers listed for the improved portion of the State Railways represents only the number in the previously quoted 23 zones and does not include the passengers outside the 23 zones.

4.4 Type of Urban Railways Recommended for Teheran City

(A) Types of Urban Railways

The types of railways used in urban areas are as follows:

1. Street-cars
2. Surface railways
3. Elevated railways
4. Subways
5. Monorails

(i) Street-cars

Thisttype replaced the original horse-drawn coaches, but under present road conditions no enterprise would contemplate the construction of this type of railway any longer, and on the contrary, tracks have already been removed or are being removed in many cities including Tokyo, for they obstruct the smooth flow of road traffic.

(ii) Surface railways

This type of railway system is most common in many countries as a means of transportation between cities. Within the city area, however, this type of railway obstructs other traffic just as streetcars do and completely divides the city into two. Therefore, this type of railway is now being replaced by elevated railways or subways in many cities.

(iii) Elevated railways

This type of railway may be constructed either by the banking method or the elevated bridge method. The method selected depends on the conditions of the proposed site and economical factors. Generally, the banking method is used where there are few buildings and where land may be procured at a low price, but it is not recommended for an area with many buildings. Elevated bridges may be constructed in a thickly housed city area but their construction in the center of the city, where there are many multi-story buildings, is not advisable because of the need to clear obstacles from the proposed route.

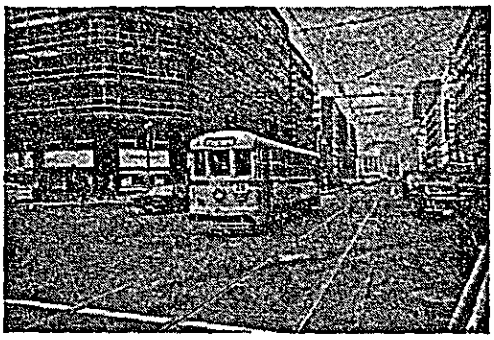


Fig. 4-4-1 Streetcar

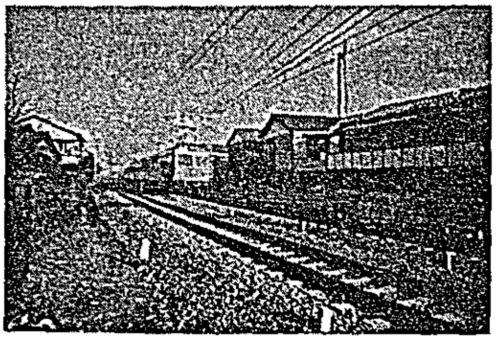


Fig. 4-4-2 Surface railway

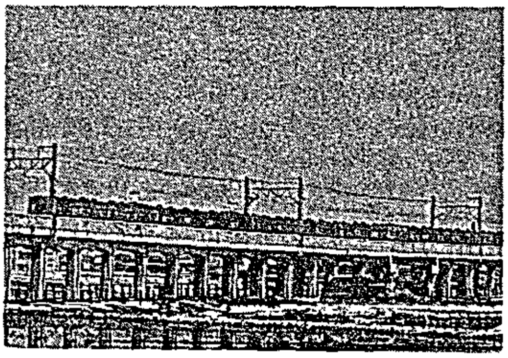


Fig. 4-4-3 Elevated railway

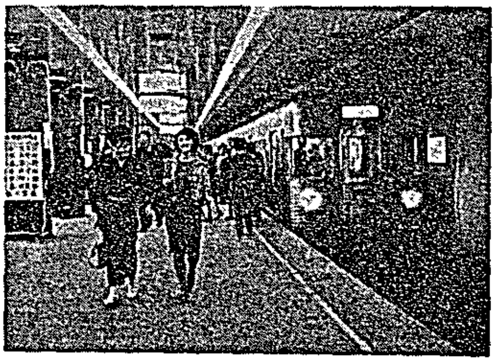


Fig. 4-4-4 Subway

Where a road is wide enough for the construction of supporting pillars, an elevated bridge may be constructed over an existing road. Even in this case, however, there should be a careful study made of the prospects for traffic conditions after its construction.

(iv) Subways

This type of railway is now employed in 45 cities of the world and it is considered the most suitable type of urban railway.

A subway does not obstruct surface traffic and does not change the appearance of the city. On the other hand, however, this system inevitably requires high construction costs and a longer construction period.

(v) Monorails

Two types of monorail are now in operation. One is the supported type (the cars are supported on a special track girder) and the other is the suspended type (the cars are suspended from a special track girder) and there is very little difference between the two. Since the girders and pillars in this system are slender in construction compared with those of an elevated railway, this system is suited for a route over a road. Moreover, the use of rubber tires provides less noise than is created by an elevated railway and as a result presents less possibility of spoiling environment. However, a practical use of this system as a means of urban transportation is seen only in Tokyo where the system connects the heart of the city with Tokyo International Airport, the others in use are only for recreational purposes. So far, this system has been little used as a means of mass transportation. The advantage of the monorail system is that the space over a road may be utilized but the problem is that there are hardly any wide roads in existing cities where a monorail system can be constructed.

(B) Type of Urban Railway Recommended for Teheran

As discussed in Section 1, "Basic Requirements for Route Selection", the construction of a railway must be based on the prospects for the future after properly evaluating the pace and the extent of the development of the area along the proposed route. For the economical construction of railways which otherwise require vast investment, it is not desirable to make an excessive investment and provide an excess of facilities at the initial stage.

Changing existing surface railways to an elevated railway and improving the banking section of the existing structure and an increase in the number of tracks the future will be extremely difficult economically, technically and also from the standpoint of land acquisition. An increase in the number of tracks in a built-up area requires a great deal of investment and time for the procurement of land. Also the work on the elevated structure involves many difficulties and presents personal hazards to the construction workers with a resultant increase in the construction costs. It is essential, therefore, that these points be given full attention in working out a plan.

For the suburban area of Teheran City, a surface railway system may be adopted but because of the rapid pace of development expected for this area, it will be more advantageous to construct an elevated railway. In particular for No. 3 and 4 Lines heading for the western suburbs, a double-track may be adequate for the initial operation, but it is advisable that adequate land space be secured for two lines or 4 tracks at least for the future. As the construction of a railway by the banking method in an area where a future city is being planned will cut the city in half and hinder the development of the area, it is advisable to adopt an elevated railway system for such an area. It would be better if roads were provided on both sides of the elevated railway so that the development of the area might be accelerated by both the railway and the roads and a better environment be provided.

In planning an urban transit network it will be advantageous for construction stage and also for the future to adopt the same standard so that cars may be transferred from one line to another and the car depot may be centralized.

When the huge construction costs are taken into consideration, the adoption of a monorail may be one of the solutions. When considering the route as having a single purpose, that of connecting the airport with the heart of the city, transportation by automobile may be inadequate to accommodate the large number of passengers and the construction of a railway may meet with difficulties in securing the required land. In such a case, if the area has already been laid out and has an appropriate road and there is a prospect that the number of road passengers will not increase in the future from the present level, a monorail will be more economical than the construction of an elevated railway.

In the case of Teheran City, the adoption of a monorail for No. 2 Line may be justified.

The foregoing discussions may be summarized as follows:

1. A subway is to be constructed in the downtown area.
2. An elevated railway system is to be adopted for the suburbs as far as in practically possible, and an elevated structure should be employed in the area where urbanization is being planned.
3. A monorail system is to be employed for No. 2 Line.

4.5 Iranian State Railways Improvement Project

The State Railways as a part of the proposed railway network

If the emphasis of the Teheran City planning project is placed on the area west of the city and if the southern boundary of the project area is the railway line, it will be natural to plan for the effective utilization of such a railway line. When the location and bearings of Karadj in relation to Teheran are taken into consideration, the traffic volume between these two areas is expected to increase rapidly.

There is very little possibility of development for the Rey district and the improvement of the existing national railway line will be more economical than the construction of another new line and will be adequate to cope with the future traffic volume. Though the Qom district and the neighboring area are not included in the city planning project, if and when the construction of an internal airport is planned for these districts, improvement and utilization of the existing railway line running to Qom will be the most appropriate means. Since the improvement of all railway lines at one time is almost impossible, they should be improved one section at a time in the right order and on a priority basis. Moreover, unless a proper judgement is made in selecting time and scope of the improvement work as to the requirement for the facility and the possibility of transferring facilities and equipment to other lines in the future by giving full consideration to the growth rate of traffic volume, there will be constant requirements for improvement work in the future, thus resulting in the wasteful repetition of investment. Therefore, this point should be given due consideration.

The improvement of the railway systems in and around Teheran City will be discussed below.

(A) Teheran-Karaj Line

Assuming that long-distance trains, freight trains, express trains and commuter trains are to operate on this line in the future, it will be necessary to increase the number of tracks from two to at least four or six. It is advisable, therefore, to procure land space for future expansion. Electrification of the line must be carried out first and station facilities matching the city plan must be provided so that the line will become the center of the regional development.

The next step will be to provide a double track, speed up the trains and gradually increase the number of tracks to cope with the growth in the volume of transportation and to designate tracks according to their purpose, such as long-distance or commuter trains, in order to increase the efficiency of transportation.

(B) Rey District

Like the Karadj district, this district may also require electrification of the line and an increase in the number of tracks in the future, but until such time the use of a diesel car will be sufficient in view of the present traffic volume. When the line has been electrified the diesel car may be transferred to other local lines. If this method is used for the improvement of the railway lines, the facility requirements may be kept to a minimum according to the needs at that particular time and the improvement of the lines may be accomplished economically. Assuming that the 20 km section in the eastern area including Rey and Teheran is made into a double-track line and the 50 km section between Rey and Karaj is electrified and equipped with automatic signal systems, the project will require 280 cars, rectifying facilities with a total capacity of 45 megawatts, a car shed and a maintenance shop with a total floor space of above 67, 000 square meters and an annual power consumption of 40, 000 megawatts per hour. The total construction costs (except for the civil works) are expected to amount to 5 billion Rials. As for the construction costs of the civil work, tracks and buildings are expected to be around 92 million Rials/km in the case of the dobule track elevated railways, and as a result the total construction costs for 20 km of double track elevated railway will amount to 1, 850 million Rials.

4.6 Railway Project

Previously in Section 4, Types of Railways Recommended for Teheran, the subway was recommended for No. 1, 3 and 4 Lines and the monorail for No. 2 Line. In this section the project and construction costs will be discussed on the assumption that the subway is adopted for all lines. Monorail will be dealt with in Section 4-7.

4.6.1 Train Operation Plan

Factors to be taken into consideration in working out a train operation plan are: the size of the transport unit (number of passengers per car and the number of cars forming a train), the frequency of operation (operation intervals) and the speed of the train.

(1) Size of Transport Unit

It is assumed that the size of a car is to be 2.88 m wide and 18 m long, and the seating capacity of a car is 150; this will be further discussed later.

The number of cars forming a train on the subway in Japan is 4 at the least and 10 at the most. The long 10-car train is operated on busy lines, but the 10-car formation is considered the limit (from a practical point of view). Therefore, a 8-6 car formation will be the most convenient. In the case of a train with a 6 car formation, the number of passengers transported by the train will be;

$$150 \times 6 = 900$$

However, when conditions are crowded, transportation efficiency may be increased to around 200% at the maximum during the rush hours and about 2,000 people may be transported by one train.

(2) Operating Headway

For urban transit, the operation time table should be such that, it provides short and equal operating headways as far as possible, so that the passengers will not have to wait long.

Though the headways may be shortened to about one and a half minutes, a two minute headway is often the practical limit in operation in view of the distance between stations, the distance between each signal and the stopping time at the stations. For this reason, trains in Tokyo are now operated at intervals of two minutes in some part but the majority are at intervals of two and a half minutes. For urban transit, meanwhile, it will be necessary to operate the trains at intervals of less than 10 minutes even in the daytime for the convenience of passengers.

In calculating operation headway based on the estimated transport capacity of each route, the factor that determines the minimum headway is the transport capacity at the busiest section during the rush hours.

The transport capacity of the line computed from the number of railway journeys concentrated on the center of the city is shown in the table below:

The table shows that on No. 1 and No. 2 Lines about 10% of the total daily passengers going in one direction are concentrated in a one hour zone during the rush hour but on No. 3 and No. 4 lines the rate of concentration during rush hour does not reach 10%. It is evident that this is a reflection of the city plan, which envisages a distribution of a sub-city-center in the western region.

(3) Operation of Trains

The present transport demands may be adequately met by the transport capacity described in 4.6.1 (2), but for special reasons such as the convenience of passengers and the need for minimizing the number of cars, the scheduled speed must be set as high as possible.

For the urban transit railway in Teheran, careful studies have been made of the line alignment, the distance between stations, the performance of cars and operating speed based onthe above viewpoint, and the operation of an express train has been planned for the section of No. 3 Line which runs parallel with No. 4 Line in the west.

The scheduled speed and its constituent factors, the average speed and maximum speed, on the basis of 20 seconds stopping time at each station, will generally be as follows:

	Scheduled speed (km/h)	Average speed (km/h)	Maximum speed (km/h)
Metropolitan area	32	42	70
Suburbs (Local trains)	45	55	80
Suburbs (Express trains)	60	70	90

Table 4-6-1 Planned maximum transport capacity and minimum operating headway

Route		Total traffic volume per day (unit:1000)	Volume of traffic in one direction per day (unit:1000)	Traffic volume per hour during rush hours (one way) (unit 1)	Planned transport capacity (unit·1)	Riding Efficiency (%)	Car formation (Cars)	Minimum operating headway (Min.)	Number of trains operated per hour (Trains)
Subway	No. 1	700	350	35,000	24,000	145	8	3	20
	No. 2	562	281	31,000	21,600	144	6	$2\frac{1}{2}$	24
	No. 3	1261	631	45,000	28,800	155	8	$2\frac{1}{2}$	24
	No. 4	912	456	33,000	21,600	149	6	$2\frac{1}{2}$	24
Improved lines of Iranian State Railways	No. 5 for Karaj	315	157	-	-	-	-	-	-
	No. 6 for Rey	310	155	-	-	-	-	-	-
	No. 7 for Qom	81	41	-	-	-	-	-	-
Total		4,141	2,071	-	-	-	-	-	-

Operating speeds and running times on each route are shown in the table below:

Table 4-6-2 Operating Speeds and Running Times on Each Route of the Subway

Items	Route No. 1 km	Route No. 2 km	Route No. 3 km	Route No. 4 km
Length of line	19.5	23.2	32.3	37.1
Number of stations (both terminals included)	16	16	19	21
Junction stations	3	3	3	3
Others	13	14	16	18
Average distance between stations	1.24	1.45	1.78	1.84
Total running time in minute	34 min	35 min	41 min	51 min
Scheduled speed	35 km/hr	40 km/hr	L=15 km 40 km/hr	42 km/hr
Maximum speed	70 km/hr	80 km/hr	90 km/hr	80 km/hr

(4) Quantity of rolling stock

If the headway is represented by h(minutes), the number of cars forming a train is by c(cars) and the scheduled speed of a train by V(km/hr), the number of cars in operation in d km of the line may be expressed in the following formula.

$$\frac{120\,d}{Vh} \times c$$

The number of cars required for the operation may be obtained from the above formula. However, as stated in 6.9.2.1, there must be reserve cars standing for inspection and maintenance, and to allow for unexpected car failure. The appropriate number of reserve cars is 15% of the total number of cars in maintained.

The total number of cars required for the Teheran Urban Transit will be as follows:

Line	Number of cars in operation	Number of cars to be maintained
No. 1 Line	176	202
No. 2 Line	168	193
No. 3 Line	280	322
No. 4 Line	258	296

4.6.2 *Construction standards*

(1) Gauges

(A) Gauge figures

The rolling stock gauges, building constructing gauges and inside dimensions of tunnels are shown in Fig. 4-6-1.

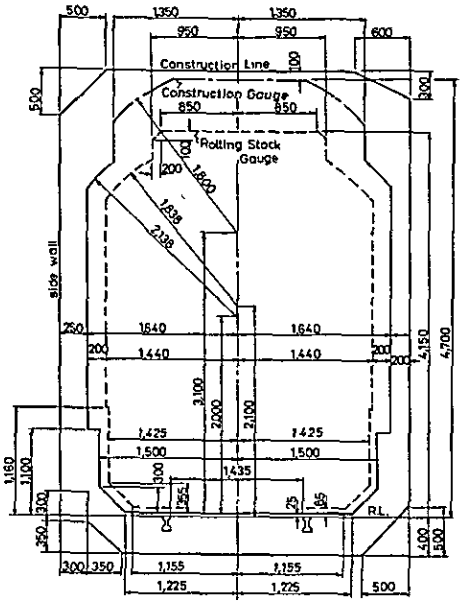


Fig. 4-6-1 Construction gauge and rolling stock gauge

(B) Track gauge

In view of an anticipated mutual train operation with the State Railways in the future, the standard gauge of 1435 mm, which is also adopted by the State Railways and most widely used in the world, is to be adopted for the urban transit system.

(C) Electrical system

For current collection, the overhead line system and the third rail system are both available. With the third rail system, the overhead space of the tunnel could be reduced (about one meter) and consequently the construction costs may be reduced by about 8%. However, when consideration is given to the future mutual service with the State Railways, it is conseivable that some sections of the line will have to be built on the ground, in which case the side third rail system may present the possibility of personal hazards. For this reason, the use of the overhead line system is recommended. In this case, the use of a special overhead current collecting system called the overhead trolley-bar system will reduce the height of the overhead current collecting system.

The power voltage for the motive power is to be 1,500 V. With this system, since higher voltage than that for the third rail system (normally 600-750V) may be used, the number of substations can be reduced.

(D) Rolling stock gauges

The rolling stock gauges shown in Fig. 4-6-1 are the boundaries setting the limit on the maximum dimensions of the each section of the car. To increase transport capacity, a wider car body is more desirable but an increase in the width of the car body results in an increase in the sectional area of the tunnel, which in turn increases construction costs. Under these two conflicting conditions, the width of car body which could satisfy the future demand for transportation in Teheran City, has been set at 2, 800 mm.

The height of the car body is to be 4150 mm from the rail level.

The height of the car should be determined on the basis of the physical standards of the people who will use this facility. The height now in use in Japan is considered appropriate and sufficient for Teheran.

(E) Length of car body

The length of the car body is to be 18 meters. To increase the transport capacity, a longer car body is desirable in principle. However, an increase in the length of the car body results in an increase in the deviation of the car body on a curve and the clearance between the end of platform and the car body, bringing about such disadvantages as an increase of the burden load of the car body on the truck. For this reason, the length of the car body is to be 18 meters.

To increase the transport capacity, it is also necessary to increase the operating speed of the train. However, in the case of an urban line like the subway, as the distance between stations is usually short, the reduction of the stopping time at each station becomes an important factor for the increase of operating speed of the train. To effect prompt loading and unloading of passengers at the station, the distances between doors in a car should not be too great. In general, a car having a body length of 20 meters requires four doors, which is one more than a car having a body length of 18 meters, but the capacity of the car does not increase in proportion to the increase of the body length. In other words, there are many cases in which an increase in body length would not contribute to an increase in the seating capacity of each train.

(F) Building construction gauges

The building construction gauges as shown in Fig. 4-6-1 are the boundaries setting a limit on the minimum space which must not be violated by structures or facilities in sections of tunnels. The clearance of 200 mm on both sides and 300 mm overhead between these structures and the rolling stock gauge is required to allow for the swinging motion of the car in operation and for maintenance work on the tracks.

(G) Inside dimensions of tunnel

For the subways, power cables, service wires and communication lines must be installed in the tunnel and workers in the tunnel must take shelter in the middle strip between the center columns. Therefore the design of the tunnel must provide a 300 mm clearance between the construction gauge and the side walls of the tunnel, and a 200 mm clearance between the construction gauge and the center column.

(2) Design standards

(A) Table of design standards

The design of the track must be based on the standards shown in Table 4-6-3.

Table 4-6-3 Design standards

		Standards	Remarks
Minimum radius of curvature	Main line	160 m	
	Line attached at the junction of main line	100 m	Radius of curvature at No 8 junction is taken into consideration
	Line along the platform	500 m	
Length of transition curve		When radius of curvature is smaller than 800 m. $L = 0.07\frac{V^3}{R}$ (m)	V: Velocity R Radius of curvature V for R is provided separately.
Distance between transition curves in opposite directions		Longer than 15 m	If impossible, straight line is not interposed
Cant		$C = 10\frac{V^2}{R}$ (mm) C: Cant (mm) V Velocity (km/h) R Radius (m)	No cant is provided where radius of curvature exceeds 800 m at the part along the platform In case radius is less than 800m, cant is provided for the train speed, 20 km/h Reduction in cant is made covering the straight length 300 times as long as the cant, where transition curve is not provided
Maximum grade	Main line	35/1000 (50/1000)	
	Within station	10/1000	
	Side Line	45/1000	Less than 3/1000 for side line where retention of car is required
Minimum grade		2/1000	Not applicable to tracks along the platform (only underground)
Minimum longitudinal curve radius		3000 m	Only when the plane curve radius is longer than 300m and when unavoidable, it can be made 2500m and 2000m respectively for the main line and side line
Enlargement of construction gange by means of curve		$W \; \frac{20,000}{R}$	W. Length to be extended on both sides (mm) R Radius of curvature (m)
Slack		Where radius of curvature is smaller than 600m $S = \frac{4500}{R} - 5$	S Length to be extended toward inward of the curve (mm) R· Curve radius (m)
Space between R L and track bed bottom	Concrete bed	400mm	500mm, in case the radius of curvature is smaller than 200m
	Ballast bed	800mm	The gravel ballast bed is used under houses or sections requireing protection from vibration
Minimumu space between centers of tracks		Surface line, 3,400 m Underground line, 4 050 m	Standard space is 3 500m for surface line, regardless of straight or curved

Notes (1) Increase of cant, slack and excess shall be reduced over the full length of the transition curve.

(2) The minimum radius of curvature indicates the radius of the inward track

(3) Relation between R and V in the formula for cant and the length of transition curve

R (m)	160	200	250	300	350	400	Over 530
V (km/h)	42	50	55	60	65	70	80

(B) Minimum radius of curve

As the minimum radius of a curve has an important bearing on the speed of the trains, it is desirable to make the radius at least 200 m so that a minimum speed of 50 km/h may be maintained. However, an increase in the radius of a curve will increase the area of exclusive use by the underground of privately owned land at the curve of small crossing angle.

Therefore, the minimum radius of a curve may perhaps be reduced to 160 m. A track with a small radial curve nut only restricts the speed of the train but causes excessive wear of rails and difficulty in track maintenance.

For the section along the platform, the minimum radius of the curve is to be kept at 500 m so that the clearance between the car body and the edge of the platform will not be too great. On a siding leading to a car shed, on which the speed of the train is not as high as on the main line, the minimum radius of a curve may be reduced to 100 m at the most.

(C) Transitional curve

A transitional curve is provided for smooth train operation.

For a curved line, in which the radius of curvature changes continuously from infinity to the radius of the curve or from the radius of the curve to infinity, a transitional curve must be provided so that the centrifugal force will change continuously when the car shifts from the straight portion to the curved portion or vice versa.

Though the transitional curve length is generally determined on the basis of hourly change of cant or on the basis of hourly change in centrifugal force or from which provides a constant multiple of reduction in consideration of the safety of the car under the conditions of three point support against derailment, the adoption of the transitional curve length provided in Table 4–6–3 will satisfy every requirement.

(D) Cant

When the train comes to a curved portion it is affected by centrifugal force corresponding to the curvature of the curved line and the speed of the train. Canting is a method in which the outer rail of the curved line is raised to provide equilibrium between the train weight and the centrifugal force. If the cant is too great there is a possibility of the train overturning when it stops on a curved line. Therefore, the maximum value of cant is to be that in which the center of gravity of the train stopped on the curved line will remain within the middle third of the track gauge and the limit of V against R is to be determined as shown in item (3) of the note to Table 4-6-3 by allowing for such elements as irregularity of track and deflection of the car spring.

(E) Gradient

Determination of the maximum gradient must be made depending on the performance of the car to be used. However, since the performance of cars used for subways is generally better than that of other cars used for surface railways, a greater maximum gradient may be taken for the subway. Generally, the maximum gradient is 35/1000 but for Teheran where the gradient is great in the northern and southern directions, a maximum gradient of 50/1000 is acceptable.

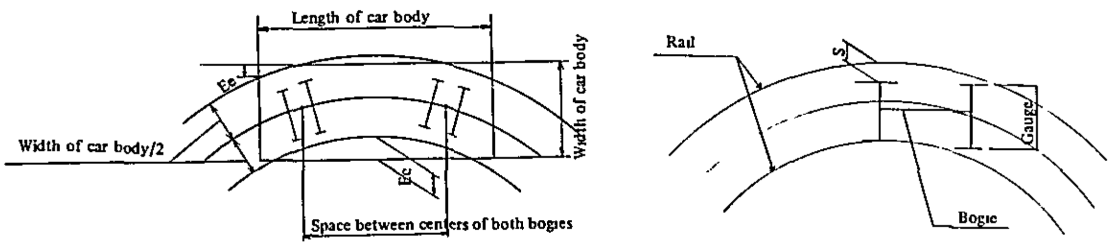
When a tunnel is constructed by the open-cut-and-cover method, the depth of the tunnel has an important bearing on the construction costs. Consequently, in a section where subway lines cross each other or where the line shifts from the underground portion to the elevated structure, a rather steep gradient will have to be used.

For the portions along the station platforms, the gradient must be gentle so that the trains may be able to stop and start with reserve traction force.

For the sidings leading to car sheds, the gradient may be great but for the lines in the car sheds or the sidings on which trains are to be in detention the gradient must be easy to prevent cars from spontaneous starting. A minimum gradient is required as the hydraulic gradient for drainage in the tunnel.

(F) Widening the restricted limits of the construction gauges and track gauge on a curved line

Widening the construction gauge on a curved portion is needed for the deviation of both ends and the center portion of the car body on a curved line and is represented by Ec and Ee in the following drawing.



Slack is the term referring to the widening of the track gauge on a curved line to provide for the smooth riding of a truck, which has two fixed axles in parallel, and is represented by S in the following drawing.

4-6-3 Design of Tunnel

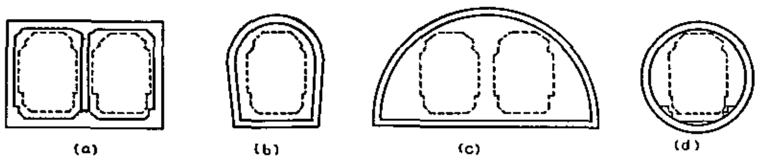


Fig. 4-6-2 (A) Roof shield tunnel

(1) Structural design of tunnel

There are three types of tunnel design, the box type, the arch type and the circular type.

The circular type is being greatly utilized in many countries in tunnel sections where the shield driving method is used. However, it is not advantageous in respect to the utilization of space for a boxcar.

The arch type construction method utilizes the technique developed years ago when large structures were built of masonry and it is presently employed in the construction of tunnels for subways and sewers. The arch type tunnel has two different shapes as shown in Figs. (b) and (c). In the case of Teheran City, when the depth of the tunnel is great or when the tunnel is to be built under the runway of an airport, excavation will have to be made horizontally by the ordinary mining method. In such a case, the type shown in (b) will probably be most suitable and require less construction.

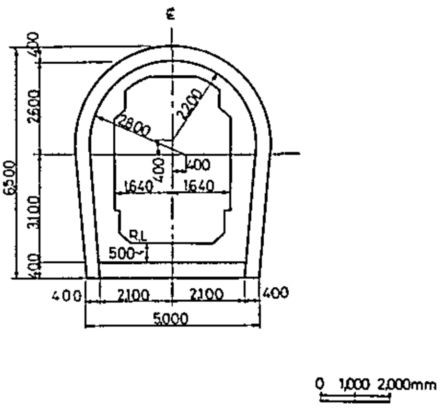


Fig. 4-6-2 (B) Roof shield tunnel

The arch type shown in (c) requires a large sectional area. This type is being gentle used in Paris and other cities which employ an island platform without columns.

When used for large span sections, it can reduce the thickness of the upper and lower slab can be reduced. When used for the section where stations are to be provided, the center of the ceiling is raised, presenting a grandeur appearance. However, attention must be paid to the fact that the increase of the span results in poor utilization of space and low efficiency of natural ventilation by the piston action of the train.

In Montreal, Canada, the rise in temperature in their recently completed double-track arch tunnel was so great due to inadequate ventilation that additional ventilation shafts had to be provided between each station.

The box shaped tunnel is most suitable for box cars and affords a maximum utilization of space in the tunnel while requiring the minimum amount of underground space, thus making room for other facilities which will have to be installed jointly. Also, because of the small clearance between the car body and the tunnel wall, there is natural ventilation by the piston action of the train.

Possible materials for the construction of this type of tunnel are stone, concrete, reinforced concrete, PS concrete and steel. However, in view of the fact that the tunnel is an underground structure, the section area should be fairly large, the work has to be done in busy city areas, many restrictions on the construction work are involved and that some alteration of design will be inevitable during the construction, reinforced concrete is considered most suitable for this type of structure. However, for specific portions such as columns in the stations and girders which requires a long span, there should be a design which also makes good use of the properties of other materials.

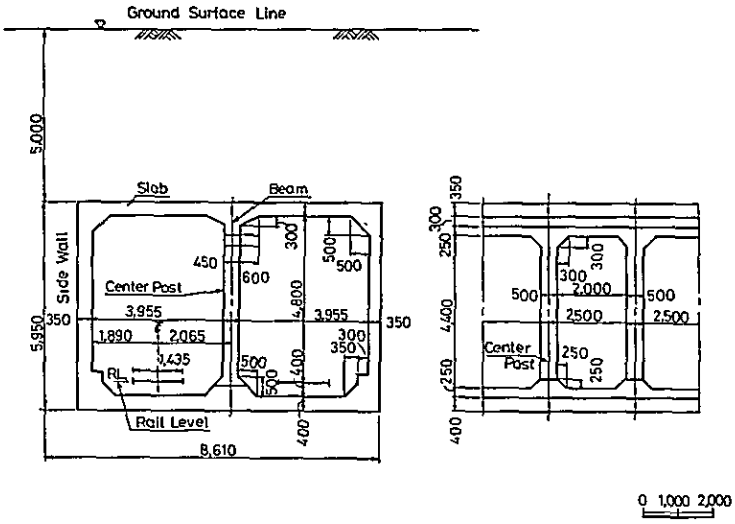


Fig. 4-6-3 Box section tunnel

In consideration of the foregoing requirements, the type of tunnel using the cut-and-cover method for subways in Teheran City should be the rigid frame reinforced concrete structure.

(2) Design load

Since the route of the subwaysis generally underground, the weight loads to be considered for the upper slab are the surface and soil loads. Soil pressure in relation to the ground water level must be taken into consideration for the side walls and the soil reaction for the bottom. When buildings are located close to the proposed route, they should also be taken intoconsideration. When the route passes under privately owned land, the design of the tunnel must be such that the base load of the existing or future buildings may be placed on the tunnel of the subway. In the case of land where there is a possibility of structures being built in the future, the tunnel should be capable of bearing the load of the foundations of a four-story reinforced concrete building, and compensation may be paid to the land owner for the restriction on the size of the building to be built.

In that case, the design of the tunnel of a subway must be able to support the base load of the building, and at the same time, a survey must have been made in advance to show that the bearing capacity of the foundations beneath the tunnel is fully able to support the load of the building.

Since underground structures are generally less susceptible to earthquakes, there will be no particular need for considering earthquake conditions in the case of Teheran City. For elevated bridges and structures on the surface, the seismological load may be considered in the same way as for a building.

(3) Water proof layer

The outside wall of the subway tunnel is covered with an asphalt layer consisting of two or three sheets of hessian cloth and felt, as a rule. This work has an important bearing on the construction of a tunnel from the standpoint of construction costs and construction time.

The ground-water level in the area north of the center of the city is siad to be more than 100 m and even in the southern half of the city centering around the Central Station it is said to be 30 m. Therefore, the water-proof layer may be eliminated except for the upper slab portion.

For water seepage in the tunnel after its completion, the capacity of the pump rooms which are to be provided at the rate of one pump for every 2 km along the entire length of the tunnel is considered sufficient.

(4) Track structure

In view of the fact that the tracks of subways are laid underground and that there is a high frequency of train operation, the subway tracks must meet the following conditions:

(A) As the maintenance of tracks during operating hours is almost impossible because of the high operating frequency, tracks must be of a type which provides high durability.

(B) Because of short non-train operating hours, tracks must be of a type which enables prompt maintenance.

(C) Tracks must be of a type which causes minimum vibration and noise.

(D) Tracks must be of a type which contributes to the maximum reduction of the section area of the tunnel.

(E) As the route has many curves with a small radius and a steep gradient the tracks must be of a type which is able to withstand the severe working load caused by these conditions.

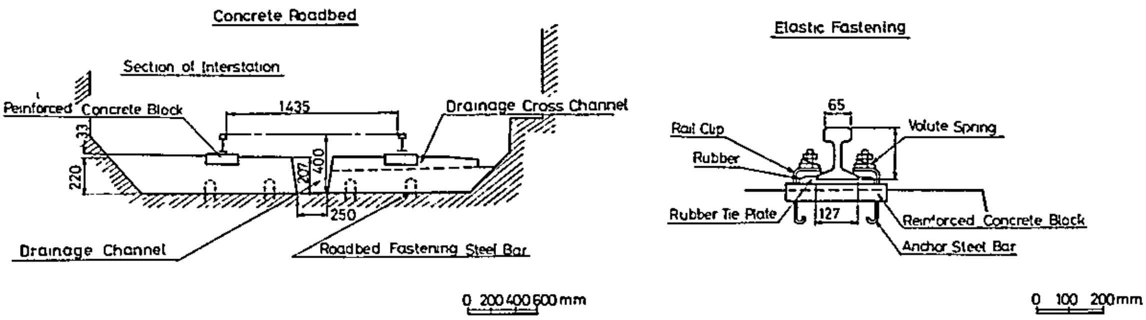


Fig. 4-6-4 Track structure for concrete roadbed

Because of the above requirements, the track must be laid on a concrete roadbed with rubber tie-plating inserted between the rail and the roadbed as shown in Fig. 4-6-4. However, for the sections passing under buildings, a ballast roadbed should be employed to minimize the effects of noise and vibration.

In the case of concrete roadbed, direct elastic fastening devices (refer to Fig. 4-6-4) fasten the rail directly to the roadbed by the insertion of a rubber pad. The rail must be of the 50 kg/m type, and a hard head rail having a high resistance against abrasion should be used for curved lines. The toe of the crossing must be of manganese steel. The joints of the rail must be welded and the number of joints must be kept to a minimum as far as possible to reduce the work load during maintenance work, to prevent noise, and to provide for the comfort of the passengers.

(5) Drainage facilities

The water to be drained from the tunnel is the water that has been used at the station, rain water coming through the openings of the ventilation ducts and the water that seeps into the tunnel. The water from these sources collects in the drain pits provided in the concrete roadbed and from there it flows down on the vertical slope of the tunnel and is collected in the catch basin of the pump station. From there the water is pumped to the sewer line.

The capacity and spacing of the pumping stations are generally determined by the climate of the region, the ground-water level and the type of station to be provided. For the subway in this city, however, a pumping station equipped with two 5-inch pumps provided for every 2 km is considered sufficient. The pumping station should be located at the concave section of the vertical slopes in principle, and it is essential that the location of the pumping station is taken into consideration when the vertical slope of the tunnel is to be determined.

For the design of the pumping station, two types, a vertical pumping station (see Fig. 4-6-5) and a horizontal pumping station (see Fig. 4-6-5) are available. Unless there are some restrictions on the availability of land space, the standard pumping station for this project should be the horizontal pump.

(6) Disaster control system

The subway, unlike the surface railways, has its tracks and stations underground. It is important, therefore, to have a complete disaster control setup capable of coping with emergencies and providing for the safety of the passengers and railway employees. Possible types of disasters are fire, flood, and power failure.

As regards fire, efforts should be made to eliminate the causes of fire. For this reason, the fire proofing of cars and restriction of installation of combustible equipment must be given full consideration. To guard against fire, thermo-type fire detectors, smoke-type fire detectors and other types must be installed for the prompt detection of a fire, and communication systems for the immediate reporting of a fire must also be provided.

Also, because of its underground structure, the design of the tunnel must be such that the exits to the surface for evacuating passengers will be concentrated in one place. Studies must also be made of the means to guide passengers in case of an emergency.

To minimize fire damage, the installation of fire-fighting equipment and the organization of fire-fighting crews must be considered. The installation of smoke eliminating facilities to prevent smoke damage and fire doors (shutters) to prevent the spread of fire must also be considered.

For the prevention of flood in the tunnel, an evaluation must first be made on the possibility of inundation of the subway on the basis of the results of surveys on the precipitation, canals, and the past records of inundation in the Teheran area. Also the required pumping capacity must be determined and the need for a water gate must be considered.

Power failure may be caused either by trouble at the power source or by a secondary cause: such as from the effects of a fire or flood. In order to secure a power supply for lighting the station precincts and operating the ventilating equipment, it will be necessary to provide emergency batteries.

(7) Ventilation facilities

In Teheran the summer season is not particularly hot except in places directly exposed to be sunlight. In the subway, however, the frequency of train operations and number of passengers will inevitably bring about high temperatures and humidity, making the subway very uncomfortable.

For the ventilation of the tunnel, natural ventilation by the piston action of the train and forced ventilation by mechanical means are available. For ordinary sections of the tunnel, the use of natural ventilation will be more economical. For this purpose, two shafts, 2.0 m x 1.3 m each, must be provided in the wall or upper slab of the tunnel and they must lead to the sidewalk or an open space, with opening covered by grilles. In this case, a means must be provided to prevent the flow of water into these shafts in the event of unexpected inundation.

In the stations where the stopping time of trains is relatively long, heat generation is considerably higher than in other sections of the tunnel and requires more ventilation. However, because of the size of the station and the features of the streets, the installation of many ventilation openings is often restricted. It is advisable, therefore, to provide forced ventilation by mechanical means at the stations. In this case, one may use either the method in which the intake of air is provided in the station and outlet of air is provided in the tunnel section or the method in which both intake and outlet are provided in the station. Selection of the type to be used should be made after considering the distance between stations and the location of the station.

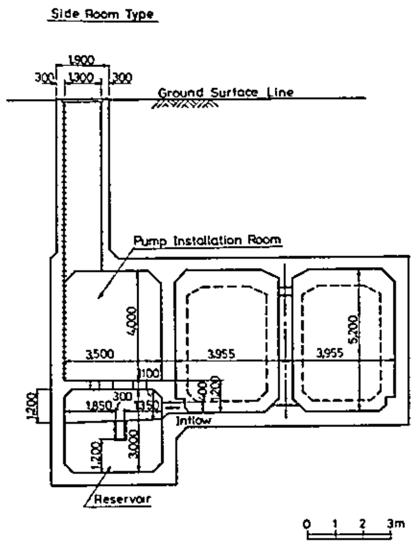


Fig. 4-6-5 Structure of drainage pump room

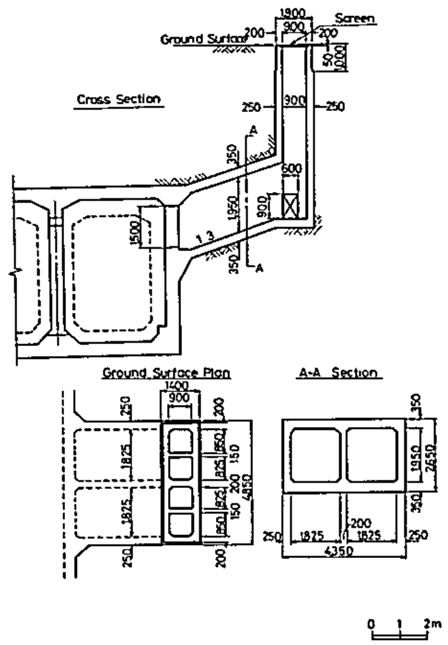


Fig. 4-6-6 Structure of ventilation

4.6.4 Design of the Elevated System

As previously stated, it is desirable that the line be brought to the surface as soon as possible after passing through the existing city area, from the standpoint of cost. In working out a plan, however, consideration must be given to the fact that the present outlying area covered by the current project will become a city area in the future.

The construction of embankments or cuttings will divide the area into two and hamper the growth of city area in the future.

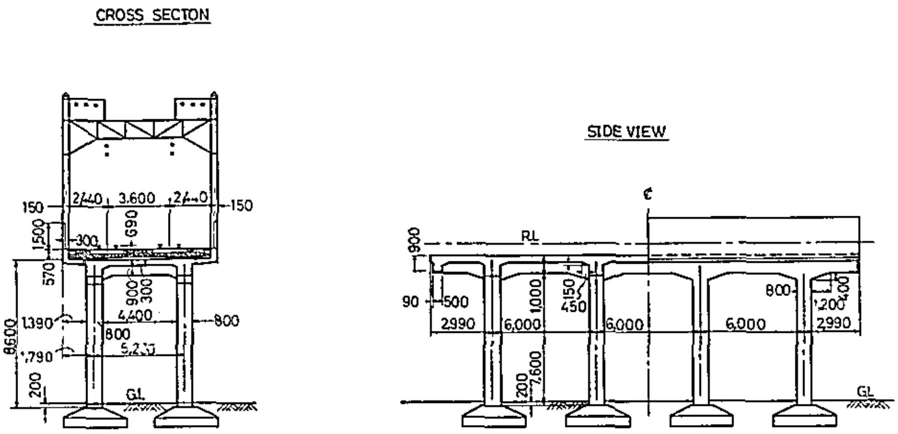


Fig. 4-6-7 Elevated railway structure

Fig. 4-6-8 Station on elevated railway

For the portion where embanking or cutting is best suited to the topography of the area, such means may be justified. Otherwise, an elevated bridge of reinforced concrete must be employed in principle. This is due to the fact that in the case of an elevated structure, more attention must be paid to noise and vibration than in the case of a tunnel. Therefore, the roadbed must be made of ballast with the use of synthetic rubber padding and an elevated structure must be made of reinforced concrete. It is desirable that a PS concrete bridge is used for a portion of the long span and that the use of steel be limited to unavoidable cases only.

4.6.5 *Stations*

(1) Size of station

Comparing construction cost of underground stations with those of the ordinary double track tunnel, the cost of the former is usually about 3 times greater than that of the latter for the same length. Consequently, the size of each station carries much weight in the total construction costs of the tunnel. However, since it is extremely difficult or almost impossible in some cases to expand or alter subway station facilities in the future, the size of each station should be determined after careful and thorough investigation.

(2) Types of platforms

The types of platforms available are the separate platform type where there are two platforms, one on both sides of the double track and the island platform type where there is one platform between the two tracks. The merits and demerits of the two types are shown in the following table.

Table 4-6-4 Types of Platform

	Items compared	Separate type	Island type
1.	Alignment of tracks	Good	Inferior, requires reverse curve
2.	Need for mezzanine floor	Not always necessary	Necessary in principle
3.	Depth of structure	Shallow	Deep
4.	Utility of space in construction	Good	Inferior, unavailable space at junction in front and in the rear of station
5.	Construction costs	Low	High
6.	Platform extension work	Possible	Almost impossible
7.	Utilization of platform	Low	High
8.	No. of ticket windows & gates, and operating costs	Separat or both sides, operating costs higher	Concentrated in one place, operating costs lower
9.	Convenience for passengers getting on & off	Inferior	Good

In general, the separate platform type seems to be more advantageous than the other. However, in view of the advantages of the island platform type, such as effective utilization of the width of the platform during rush hours, and its convenience in boarding and changing trains at junctions, as a rule the island platform type should be used in the downtown area and the separate platform type in other stations.

(3) Length and width of the platforms

The length of the platforms must be determined on the basis of the maximum train length including an allowance for stopping based on the motormen's skill. If a train is composed of 6 cars, the maximum length will be 6 x 18 m = 108 m, plus an extra 5 meters at each end, making the total length of the platforms 108 + 5 x 2 = 118 m.

The width of the platform' should be determined on the basis of the present and future number of passengers. In this case, however, the standard width should be 4.0 m for each of the separate platforms and 8.0 m for the island platform. Studies should also be made of the requirements for widening the platforms at key stations such as the one located at the junction of No. 1 and No. 2 lines. The allowable minimum width is to be 3.5 m for each of the separate platforms and 7.0 m for the island platform.

(4) Standard type of stations

Standard types of stations include the island platform type with mezzanine as shown in Fig. 4-6-9, the separate platform with mezzanine as shown in Fig. 4-6-10 and the separate platform without mezzanine as shown in Fig. 4-6-10.

For the type shown in Fig. 4-6-11, an underpass should be provided under the tunnel to connect the platforms.

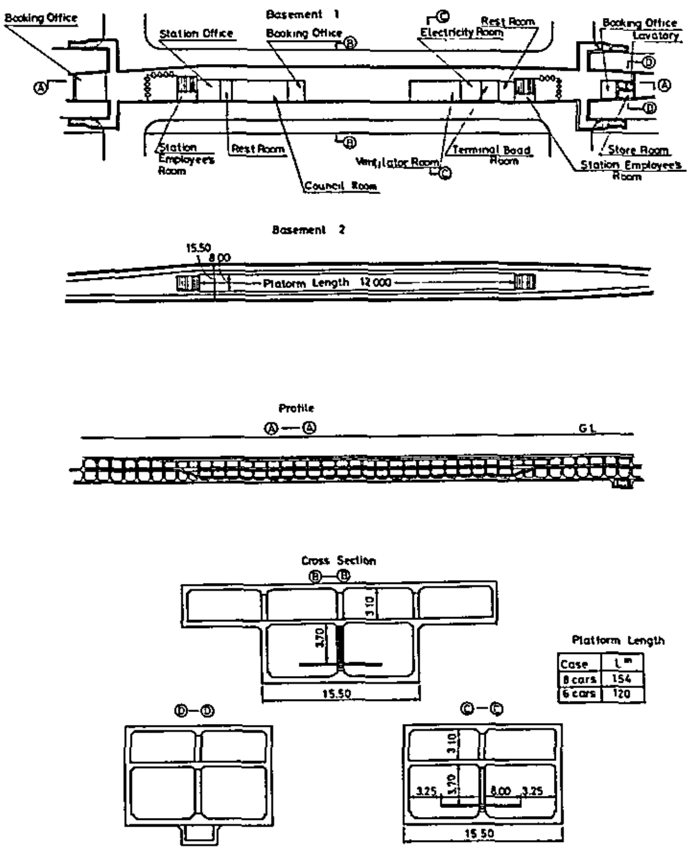
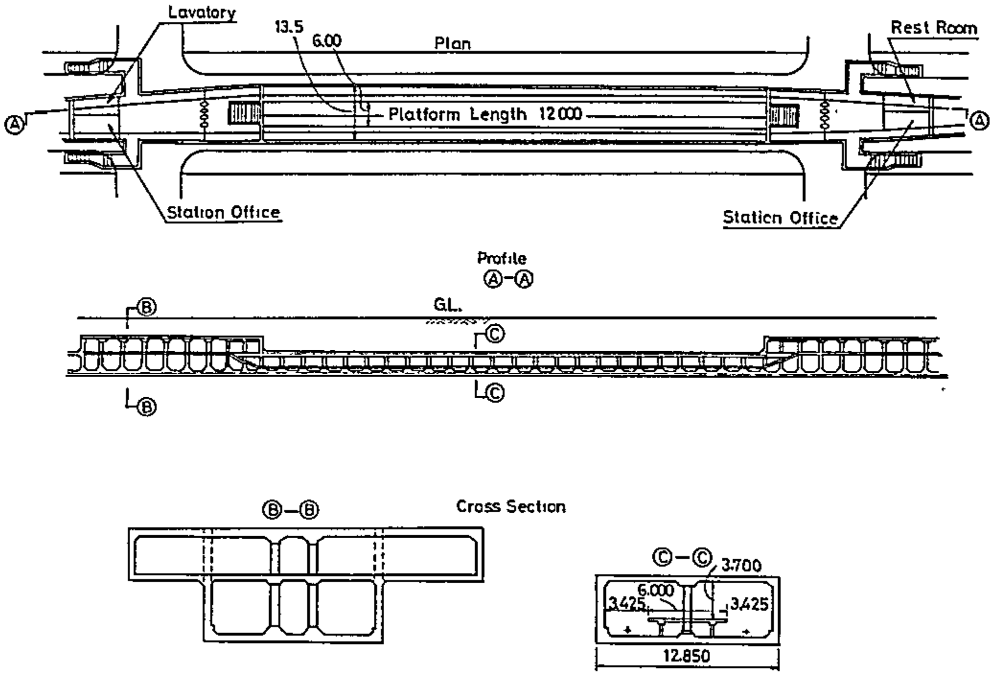


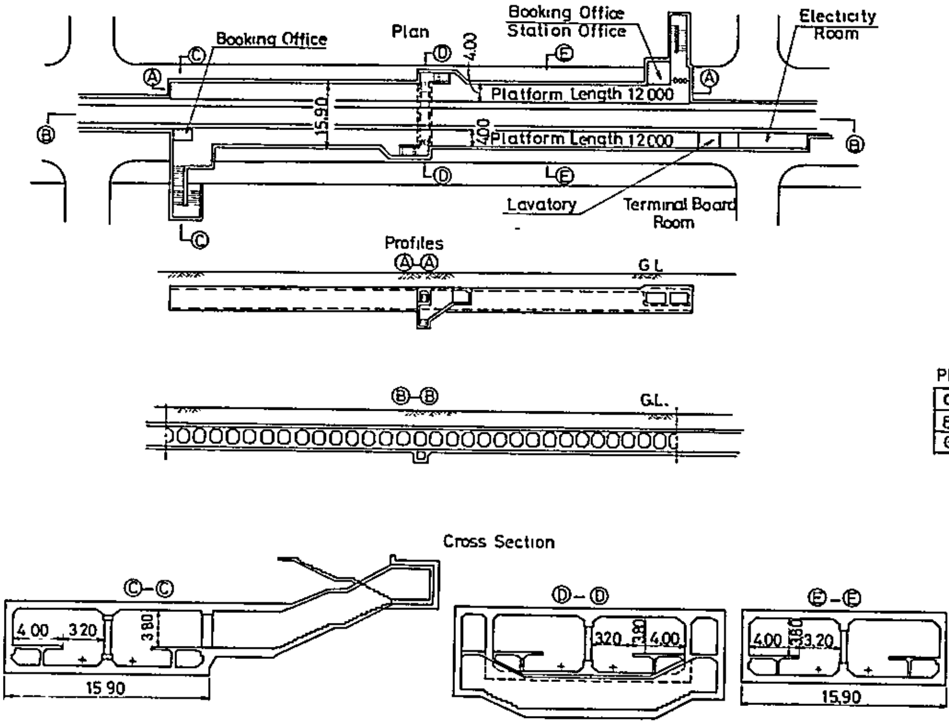
Fig. 4-6-9 General plan of station (Type I)



Platform Length

Case	L^m
8cars	154
6cars	120

Fig. 4-6-10 General plan of station (Type II)



Platform Length

Case	L^m
8cars	154
6cars	120

Fig. 4-6-11 General plan of station (Type III)

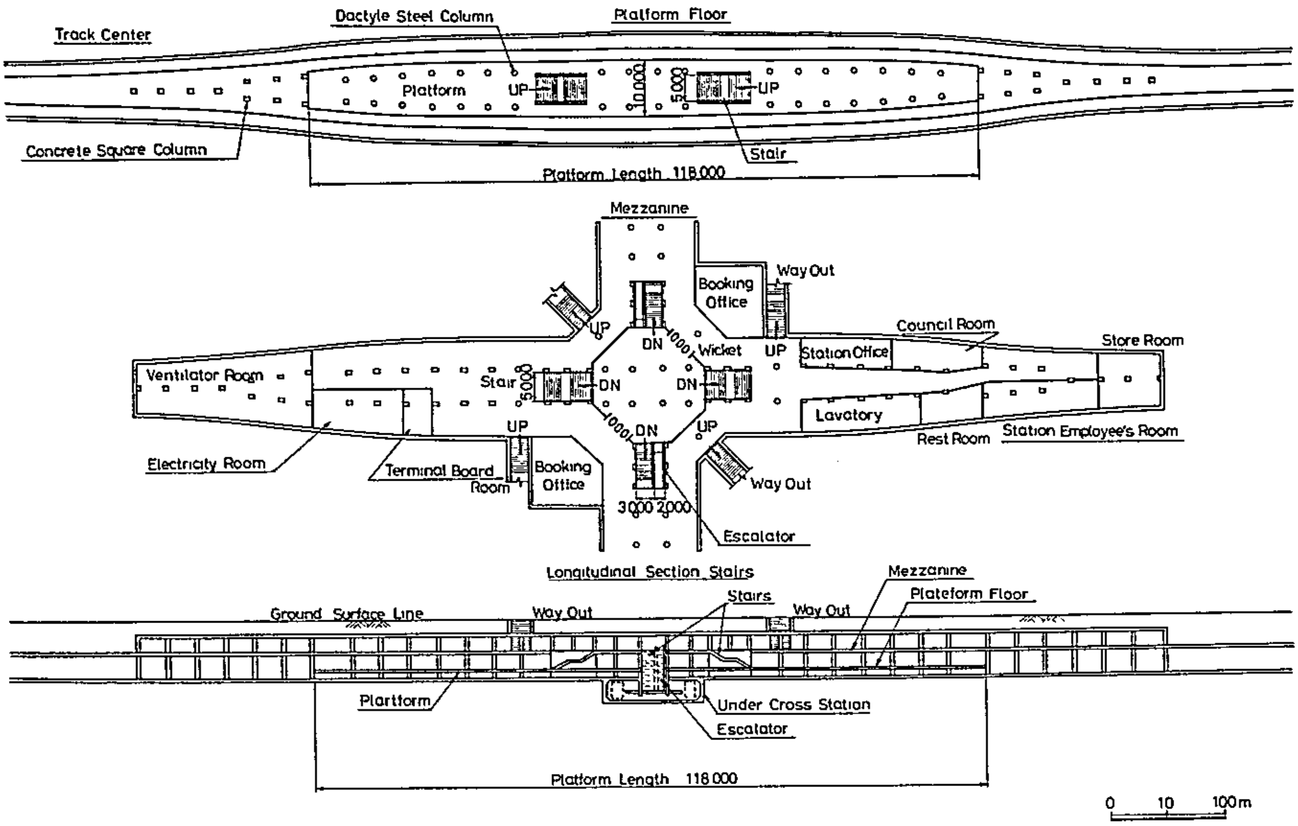


Fig. 4-6-12 General plan of cross station

Figs. 4-6-12, 4-6-13 show the general plan of a junction station in the downtown area.

It is desirable that the lower platforms be equipped with escalators.

For effective utilization of the platform space, columns on the platform should be of ductile cast iron to minimize the area occupied.

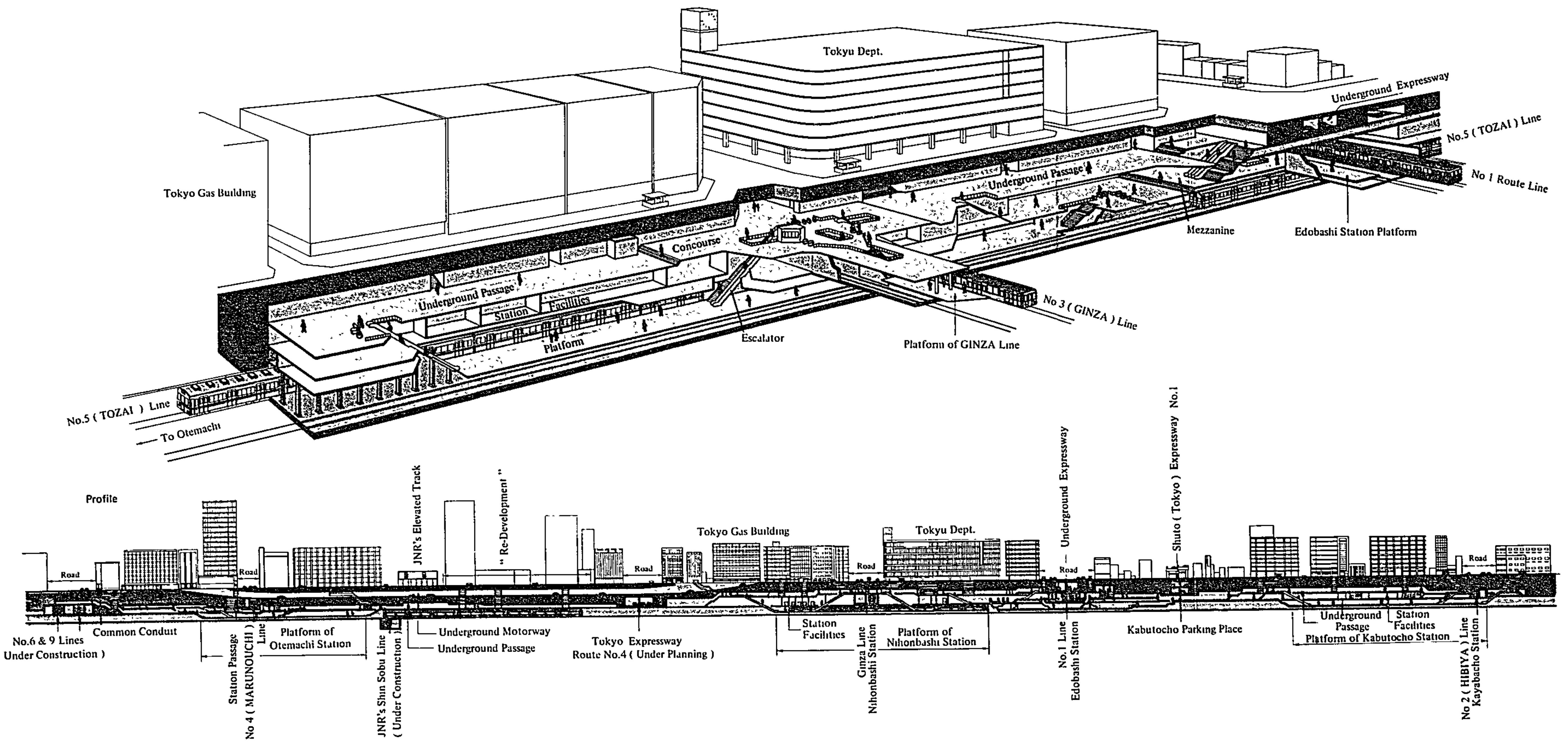


FIG. 4 — 6 — 13 BIRD'S-EYE VIEW OF CROSS STATION

(Nihon-Bashi Station on No. 5 Line Tokyo)

(5) Station facilities

The facilities required for each station will be as follows:

(A) Booking offices: Payment of fares is to be made by the flat fare token system and tickets are to be sold mainly by vending machines. Windows only for the changing of money are to be provided. An arrangement where the back of each machine is facing the ticket office affords the convenience of easy inspection and maintenance.

(B) Wickets: Automatic gate machines, which allow passengers to go through the wicket one at a time when a token is deposited, should be provided in a location where the machines can be seen from the ticket office.

(C) Station operating facilities: The facilities required for the accomplishment of a station's activities are; offices, a lounge, a bed room, a conference room, a toilet for station employees, a store room and a hot water service room. However, there will be no need for provide an office and a conference room for every station.

(D) Electrical facilities: Electrical facilities needed are; a power room to receive high voltage power from sub-stations, a terminal panel room and a battery room to secure a minimum power supply for precautionary purposes.

(E) Lavatory: Though the construction of a lavatory for passengers' use at each station may result in an increase of the total construction costs and maintenance costs, it is desirable to provide a lavatory for passengers at each station, the size of which may be kept to a minimum in proportion to the number of passengers.

(6) Entrances to the stations

Entrances to the stations may be located near a public square, on a sidewalk or on privately owned land facing the street. Entrances provided near a public square are easily recognized by passengers, but the selection of their location must be made after careful studies have been made of the convenience to passengers when transferring to buses and taxis and their relation to pedestrian crossings. Their appearance must suit the overall arrangement of the public area.

Entrances provided on the sidewalks are most convenient for the passengers, but unless the sidewalk is wide enough, the entrance (provided on the sidewalk) obstructs the pedestrians traffic. In Tokyo an entrance is not permitted on sidewalks unless the width of the sidewalk is more than 5 m. The width of a subway entrance must be 1. 5 m at the minimum.

When an entrance is to be provided on privately owned land it should be located in a lot facing the street under which the subway is running, wherever practical, and there must be conspicuous signs posted to show the location of the entrance. Lots facing a street under which a subway is running are generally of high value. Therefore, effective utilization of these lots should be contemplated by building structures over the entrance or using the basement of the structures for entrances to the subway.

In either case, it is most important to provide standard consicuous signs which can be easily recognized day and night at the entrance for the benefit of passengers and to attract more passengers.

4.6.6 Construction work

The construction of a railway requires a long period of time using the same construction methods repeatedly for the majority of the construction works. Therefore, each country or city has its own construction methods adapted to its specific conditions and environment, and can rely on these methods.

It is believed that the selection of one particular construction method best suited to Teheran, avoiding hasty initial construction methods, will be the most economical way for Teheran City.

In selecting a construction method, consideration must be given not only to such natural conditions as soil, topography and ground-water, and such specific requirements peculiar to the proposed site as the above-ground and underground structures but also to the availability of construction materials.

In Teheran, the use of steel and lumber in large quantity is difficult and the use of heavy construction equipment is also expected to be restricted to some extent. With these facts taken into consideration, the construction method to be employed will be discussed below.

(1) Natural conditions such as geology and groundwater

The city of Teheran is situated on a fan-shaped plain at the southern foot of the Elburr mountain range. There are several valleys within the city and a voluminous rapid flow of water is expected when it rains. The soils have a high consistency, comprising a mixture of gravel, sand and clay. Even in vertical excavations it is expected that the walls will not cave in if adequate measures are taken to prevent streams of underground water.

As the ground-water level in the high land in the vicinity of Abbass-Abad is expected to be at a depth of more than 100 m underground, and in the low land near the station at 30 m, there will be no need for considering ground-water in designing the excavation method. If any problem arises in relation to ground-water, it may be settled at that particular time.

Though this region is within the seismic zone which runs from Turkey to northern India, earthquakes are not frequent, and therefore, there will be no need to consider earthquakes in selecting a construction method.

(2) Cut and cover method (without surface planking)

As stated previously, the soils in this area consist of a mixture of gravel and clay and have a high consistency with N value of more than 50. Consequently, it will be the more advantageous to excavate by blocking traffic but without providing surface planking. Where deep vertical excavation presents the possibility of a cave in, proper treatment of face of slope must be provided. Cut and cover without surface planking does not require surface cross-beams and provides free excavation and results in a reduction of construction costs and time.

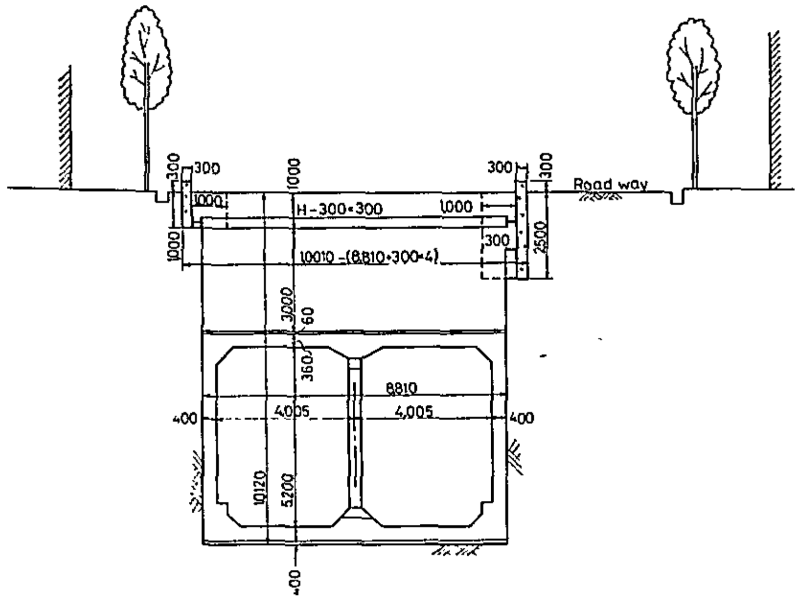


Fig. 4-6-14 Cut and cover method without surface planking

(3) Cut and cover method (with surface planking)

For the portion where main roads cross each other, there must be surface planking provided. For some roads, a special road for construction work is necessary along the subway route, in which case lagging must be provided. In this case, the use of the wall retaining method in which H-beams are piled vertically is almost inconceivable because of the soil conditions at the proposed site, also the re-use of beams for the next job is not conceivable either.

Where one side of the road is being used by vehicles for construction purposes, it will be necessary to protect the side face against collapsing due to vehicular traffic. The upper portion may be protected with a concrete wall about 30 cm thick and the lower portion may be protected in the same manner as the portion requiring no surface planking. It will be necessary to provide struts in the portion which supports the concrete wall and raise the wall so that it will stick out of the ground about 30 cm to prevent water from flowing into the tunnel. For the portion requiring surface planking, cast-in reinforced concrete piles of 600 mm diameter should be driven in at intervals of 3.5 m to support 600 mm H-beam girders on which 300 mm joists are to be placed. Surface planking is to be placed on the joists. Over the planking wood, a steel or PS concrete linking boards are to be placed.

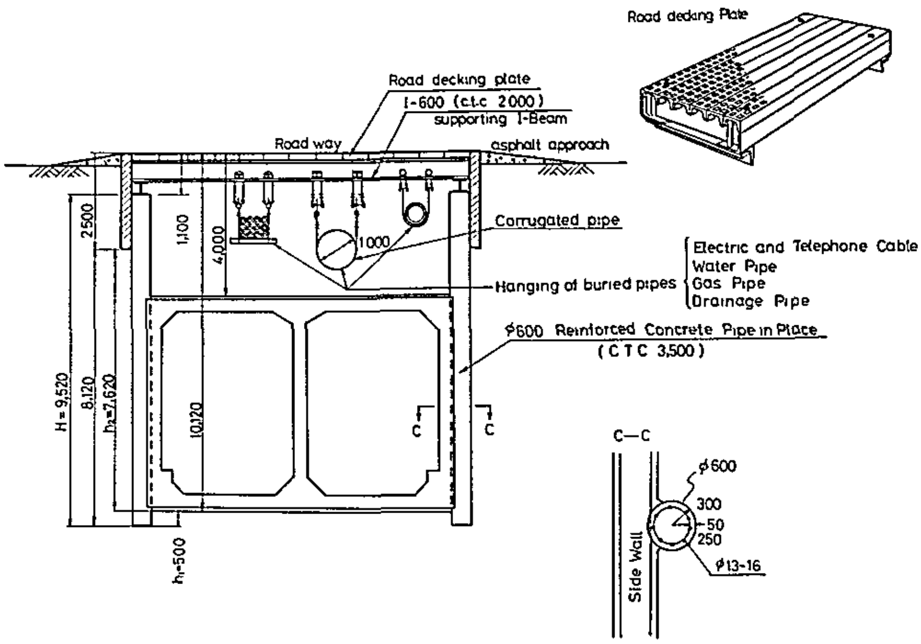


Fig. 4-6-15 Cut and cover method with surface planking and handling of buried pipes

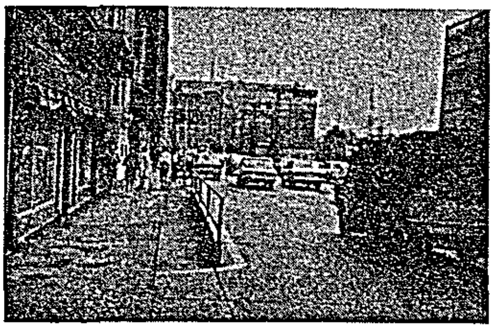


Fig. 4-6-16 Road surface cover

(4) Surface planking

The use of wooden planks is not advisable in Iran where wood resources are not abundant. Steel planks are expensive but because of their durability, their use will be more economical when their re-use is taken into consideration.

The use of PS concrete for planking is not advantageous because of the increase in the weight and also because the concrete is highly subject to damage depending on the way it is handled. Therefore, the use of concrete is not economical in some respects.

(5) Shield tunneling method

With this method, a steel cylinder-shaped tunnel excavator moves ahead of the construction of the tunnel and the work may be accomplished independent of the ground surface.

In Teheran where soil conditions are favorable and there is no problem of ground-water, a simplified shield tunneling method is recommended.

In the portions where the route deviates from the road in the downtown area, the use of a method similar to the ordinary one is not feasible because the route must run below many structures with cess pools located nearby. It will be necessary, therefore, to mend these cess pools along the route in advance by mortar injection and other means.

(6) Ordinary tunnel excavation method

The line heading for Tajrish passes through a desert area. In this area the overburden is fairly deep and therefore the use of an ordinary mining method is considered appropriate. However, unlike the downtown area, there are no buildings or cess pools in this area, and therefore the use of the shield tunneling method will not be required.

(7) Handling of underground utilities

In the city streets there are always some sewer lines, main water lines, gas pipes and power cables buried underground. It will be necessary, therefore, to take appropriate measures for the protection of these utilities against damage during construction work.

Sewer lines:

The sewer lines are one of the most troublesome elements in the construction of subways. Fortunately, there are no sewer lines in Teheran but the proposed route must cross the point where drainage pipes are provided for use in case of inundation. Since the construction of sewer pipes is necessary for the city when future development is taken into consideration, there should be room left the construction of sewer lines when constructing the subways. Though the size of the drain pipes for inundations is fairly large, these pipes may be replaced with corrugated pipes and suspended for their protection against damage and may be reinstalled after the completion of the tunnel.

Main water lines:

The main water lines may be protected from damage by being suspended during the construction work. In this case, however, the joints of the pipes must certainly be reinforced to prevent leakage. It will also be necessary to familiarize the workers with the location of stop valves in case of an accident and to take measures to supply water at specific points even when the valves are closed.

Power cables:

Power cables may be suspended for protection against damage during the construction period. As the handling of power cables is difficult, particular care must be exercised when working with them.

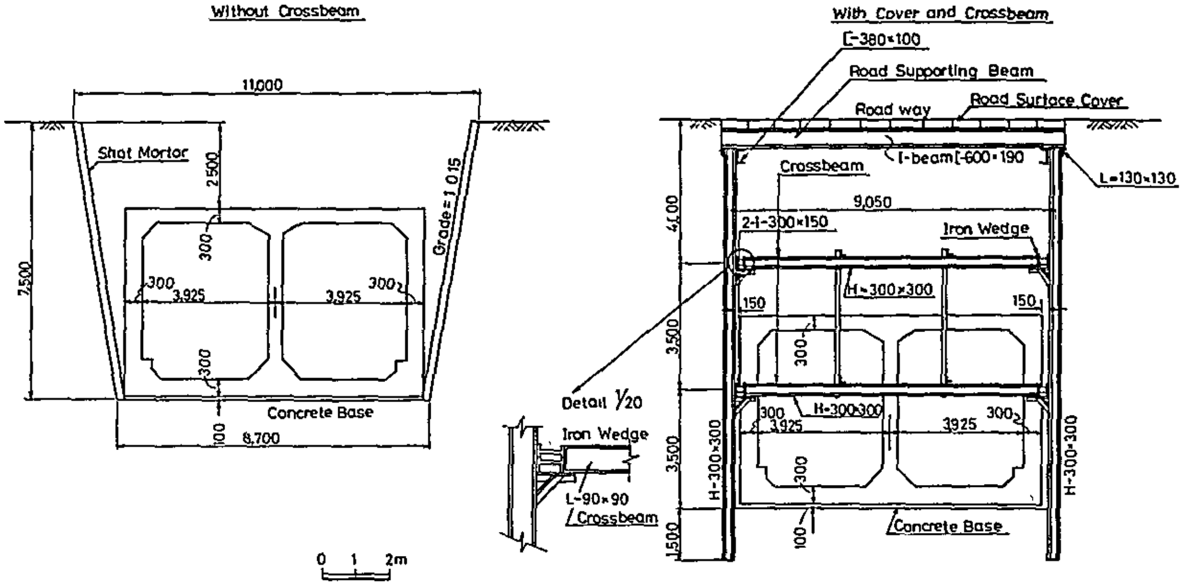


Fig. 4-6-17 Standard open cut excavation method used in Tokyo

Fig. 4-6-16 shows a typical open-cut method with steel piling as employed in Tokyo and other countries in the world. The construction costs are based on the methods shown in Fig. 4-6-14 and 4-6-15, which are best suited to Teheran City and require less construction costs.

4.6.7 Electric Facilities

4.6.7.1 Power System

(A) Arrangement of Power Engines of Trains

As the city of Teheran is situated on a steep slope from south to north, it is believed that the distributed engine system which provides power engine on each car ot the train is more advantageous for the rapid transit to be installed in Teheran than the locomotive traction system with centralized power engine. Reasons are:

(1) As the character of rapid transit railways, in order to minimize the drop of schedule speed by maintaining high schedule speed even in the graded section, output of power engines on each train unit must be high enough. Then distributed power engines rather than centralized one can reduce axial load considerably, bringing many advantages such as less burden on track and others.

(2) The number of driving axles has to be increased to prevent slip of driving wheels in the graded sections.

(3) Separation and grouping of trains are easily accomplished according to the volume of transportation. Shuttle in the short distance becomes much easier if the number of locomotives is not enough. Inspection, maintenance and shifting of rolling stock also become easier.

From the above reasons, the distributed engine system is more suitable for the metropolitan rapid transit which requires efficient and flexible operation of trains.

(B) Selection of Power

If the distributed power engine system will be adopted, the conceivable type of motive power will be internal combustion engines or electric motor. Then the type of rolling stock will be either diesel car or electric car.

(1) Economical Feature of Train

Compared with diesel cars, electric cars require extra facilities such as railway sub-stationsand overhead contact lines for the supply of electric power. In the case of Iranian State Railways, gasoline is available at a low cost in Iran and then, the cost of power of electric cars is estimated slightly higher.

On the other hand, initial procurement cost and maintenance cost of diesel cars are higher than electric cars. Consequently, if equipment investment (interest and depreciation), power cost and maintenance cost are taken into consideration, diesel cars are more advantageous than electric cars when the operation density is low. However, the electric cars have more merits in case the operation density is high.

(2) Performance

a. Electric cars provide high power output per unit weight compared with diesel cars, and are suitable for high acceleration.

c. Electric motor is suitable for advanced and complicated control system such as constant speed control, automatic speed control and interlock control system in conjunction with pneumatic brake system.

d. Electric cars collect power from the ground source and the power required for electric motor, electric heater, ventilator and air-condition system is easily available through overhead contact lines. On the other hand, any failure of ground facilities such as the break of overhead contact lines, or failure of substations affects operation of train in wide range.

e. Diesel cars are inferior to electric cars as far as the vibration and noises are concerned. Moreover diesel cars discharge exhaust gas and are impossible to use for subway. It is necessary for the urban rapid transit to maintain high density of train operation as well as high schedule speed by increasing acceleration and if it is indispensable for the urban transit to take underground structure in the center of the city, no one doubts that electric system is the only way of motive power for urban transit.

(C) Electric System

(1) Working Voltage

As for the working voltage, the higher is the better from the standpoint of preventing power loss and voltage drop, however lower voltage is preferable from the viewpoint of insulation.

As to the selection of type of current, alternative current is easy for step up and down of the voltage and easy to feed at high voltage, whereas, direct current is appropriate for feeding DC series motor which is the best suitable type for the electric motor of electric cars. D.C. 1,500-volt is recommended as the most suitable working voltage for the Metropolitan Teheran Rapid Transit.

(2) Power Feeding System

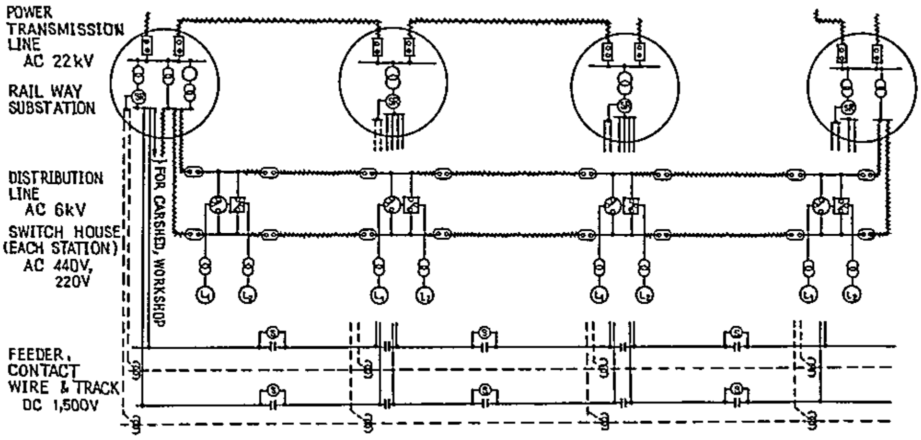
Various methods are conceivable to feed power from a railway substation to electric cars, and there are many combination of the positive side (from a substa station to electric cars) and the negative side (from electric cars to a substation). One is the utilization of overhead contact lines or ground line (third rail) for positive and ground line (running rail) for negative, and the other is counter combination of the same. Although from the economical point of view the use of running rail for negative and the third rail for positive can minimize sectional area of tunnel and is the most economical. If availability of high tension power and possibility of run-through operation of the state railway and other factors are taken into consideration, the best power feeding system for Metropolitan Teheran Urban Transit is overhead contact line system.

4.6.7.2 Railway Substations

(A) Power Reception

To maintain the stability of power feeding system, inter-connecting power transmission lines are to be provided between each railway substation, and power is to be supplied to a group of several substations from adjacent general substations of the power supply company through the exclusive transmission lines. For the railway substations that the installation of inter-connecting transmission lines is not feasible, electric power is to be supplied from adjacent substations of the power supply company through double lines (Refer to Fig. 4-6-18).

As the working voltage of the transmission lines is expected to bé 20 KV, the power shall be supplied by underground cable in the central area of the city and by overhead lines in the suburbs. For interconnecting transmission lines between respective railway substations, power cables are to be installed in the concrete trough built along the railway track. (Refer to Fig. 4-6-20 and 4-6-21.)



SYMBOL	TERM	SYMBOL	TERM
~~	CABLES	-⊘	DOUBLE-THROW AUTOMATIC OIL SWITCH
-⊟-	HIGHTENSION CIRCUIT BREAKER	⊠-	DOUBLE-THROW MANUAL OIL SWITCH
-OO-	TRANSFORMER	-||-	DEAD SECTION
Ⓢ	SILICON RECTIFIER	┌Ⓢ┐	REMOTE MANIPULATED SECTION SWITCH
Ⓖ	POWER GENERATOR(IN EMERGENCY)	∃	INPEDANCE BOND
-⊖-	SINGLE THROW MANUAL OIL SWITCH	---	DC NEGATIVE CIRCUIT

NOTES L_1 SIGNAL, DRAINAGEPUMP, LIGHTING IN TUNNEL, CHAREGER, ETC.

L_2 LIGHTING IN STATION, VENTILATOR ESCARATOR, ETC.

Fig. 4-6-18 Power Supply System

(B) Power Transformer

(1) Unit Power Consumption

Although there are different ways of calculating the power consumed by trains, a relatively simple and convenient way is to employ the unit power consumption.

One of the basic units is expressed by the average electric power (kilowatt hour) required for an object of one ton in weight to travel one kilometer. This unit can be obtained by the following theoretical formula.

$$\frac{9.8\,k_1}{3.6 \times 10^3}\left\{\frac{31}{3.6 \times 10^3}\cdot\frac{V \cdot V_m}{S}K_2 + (\text{running resistance + grade and rail resistance})\right\}$$

Where, K_1 is a coefficient for the compensation of feeding power loss and approximately 1.1, S is the average distance between stations (kilometer), and V is the schedule speed (kilometer per hour). V_m is the maximum speed at power running (kilometer per hour), K_2 is the average number of power running between stations and the running resistance is given by kilogram per ton against the average speed between stations. The grade resistance here is 1/2 of the average grade in per cent (kilogram per ton). Besides, there are other resistances including curve resistance but it is negligibly small. The unit power consumption per ton-kilometer for the rapid transit of Teheran calculated by the above formula are shown in the left column of the following table:

The average power energy (kilowatt hour) required by a car to travel one kilometer can also be used as one of the unit power consumption. Assuming that the tare weight of a car used on the rapid transit of Teheran is 33 tons and the capacity of the car is 150 passengers, the average power energy required by one car to travel one kilometer, including 10% additional power required for lighting, heating and ventilation is given at the right column of the following table:

Unit Power Consumption	KWHr/t. Km	KWHr/C. Km
Central City		
Steep Grade Section	0.121	4.6
Others	0.070	3.2
Suburbs		
Steep Grade Section	0.113	5.2
Others	0.063	2.9
Express Train Section	0.052	2.4

(2) Required Power Energy

If the unit power consumption is to be expressed by w (Kwh/car-km), the area to be covered by a substation is L(km), operating headway of trains within the section L by h (minute) and the number of cars forming a train by c (car), the average power y (Kwh) required for the said section can be given by the following formula:

$$y = \left\{ \left(\frac{60}{h} \times 2\right) L \times c \right\} \cdot w$$

In addition to the above, the electric power to be supplied by substations includes auxiliary power consumed by signals, lighting of station buildings and tunnels, heating and others. In Japan, for example, such power requirements are estimated approximately 20% of the total electric power consumed.

The estimated total power for both train operation and auxiliaries for the Teheran Rapid Transit Railways is as follows:

Lines	No. 1 line	No. 2 line	No. 3 line (Express train sections are not included)	No. 3 line (Express train sections)	No. 4 line	Total
Hourly power consumption at the rush hour(y) MWH	33.6	26.5	30.3	19.6	38.6	148.6
Annual power consumption 10^3 MWH	40.9	32.2	36.9	23.8	47.0	180.8

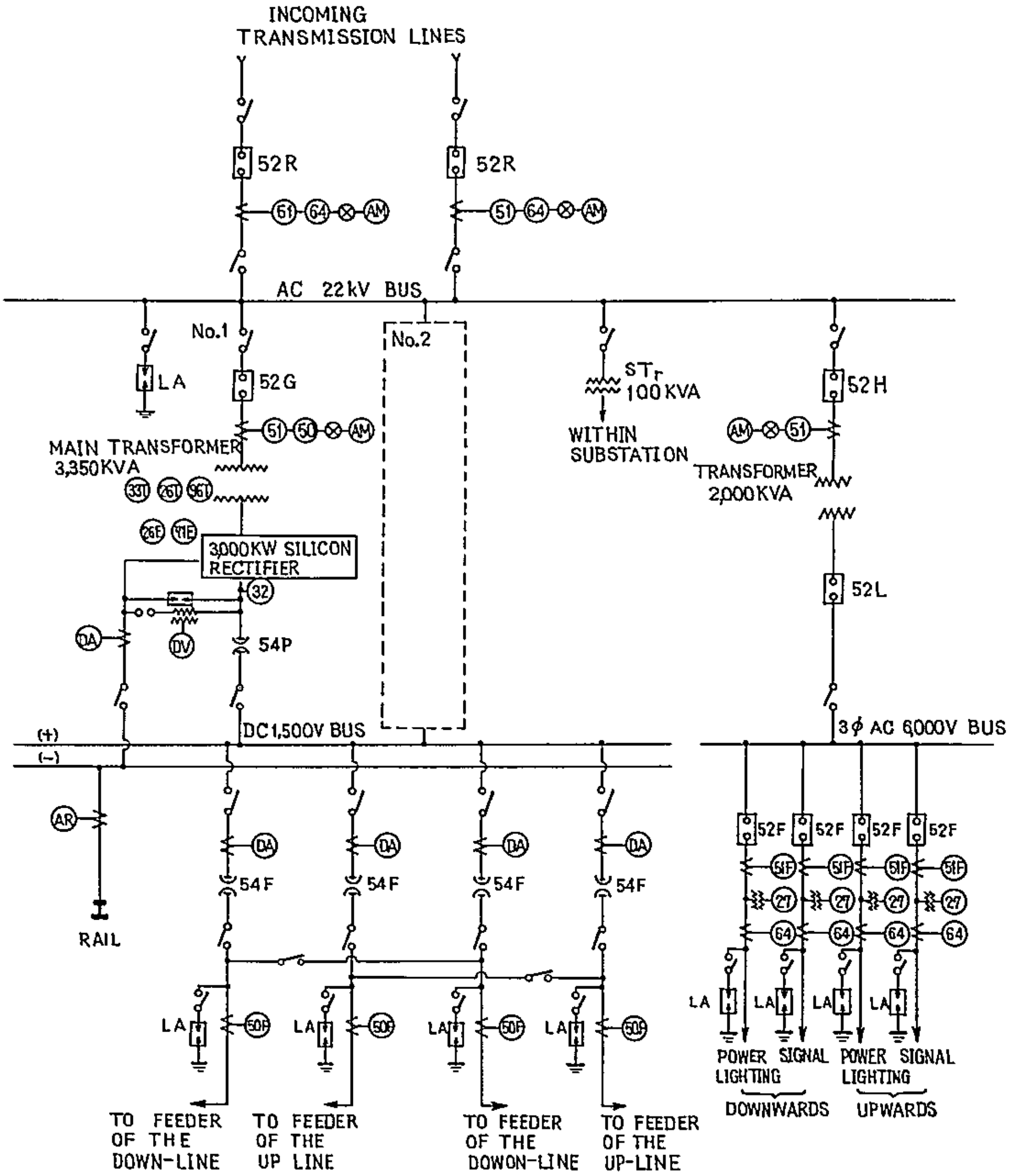
(3) Type and Capacity of Rectifiers

There are different type of rectifiers that can change alternative current into D.C. 1500-volt for the operation of train, such as motor generator, rotary converter, mercury vapor rectifier and silicon rectifier, however the silicon rectifier is the most appropriate one because of easy control and maintenance. Because of greater fluctuation of the car load and short period of peak load of the train, the economical rectifiers to be selected should be of a small continuous output with a large overload capacity. As to the capacity of individual rectifiers, the larger capacity one is more economical than smaller. However, the device of larger capacity presents various problems on maintenance and measures against failure, so appropriate maximum capacity will be 3000 kw.

The number of rectifiers required for respective lines calculated on the basis of power required for train operation estimated in the previous paragraph (1) and (2) is as follows: For practical use, however, the number to be provided should include one spare unit for every three units for maintenance and shooting trouble of units.

Lines	No. 1 line	No. 2 line	No. 3 line (Express train sections are not included)	No. 3 line (Express train sections)	No. 4 line	Total
Number of Devices required	10	8	9	6	11	44
Number of Devices to be provided	15	12	14	9	17	67

As shown in Fig. 4-6-19, the rectifiers must be equipped with protective relays and capacitors enable to protect the facilities.



SYMBOL	RELAY	SYMBOL	RELAY
(26)	TEMPERATURE	(51)	OVERCURRENT
(27)	UNDER VOLTAGE	(64)	GROUND
(32)	DC REVERSE CURRENT	(71)	SILICON FAULT CELL DETECTING
(33)	OIL LEVEL	(96)	BUCH HOLTZ
(50)	OVERCURRENT (HIGH SPEED)		

Fig. 4-6-19 Standard connection diagram of power supply circuit in substation

(C) Operation of Equipment

For the purpose of the effective operation of rectifiers, proper administration in the case of shooting trouble on the electrical system and saving of labour cost, it is desirable that the major equipments such as rectifiers and circuit breakers together with the other substation operation shall be controlled by the remote control system from the power control center.

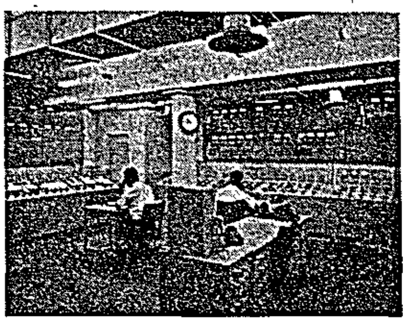


Fig. 4-6-22 Power control center

Figure 4-6-22 shows an example of power control center.

(D) Arrangement of Railway Substations

Though the distance between railway substations depends on the capacity of rectifiers to be provided, voltage drop in the overhead contact lines is the most important factor. In the section where density of train operation is higher and consequently the load is heavy, distance of substations must be much shorter. Where D.C. 1500 volt working, the distance between each substation shall be from 4 to 6 kilometers. An area of 500 to 1000 square meters of land is generally required for substation building. It is more economical to build it as an annex to the existing station building as a part of underground or on the elevated structures than to provide it separately.

4.6.7.3 Overhead Contact Lines for Electric Train

(A) Overhead Contact Wire

Grooved hard drawn copper wires *having a nominal cross-sectional* area of 110 mm^2 are to be used for overhead contact wires which make contact with the current collectors (pantograph) to supply power to the train. The ideal installation of overhead contact wires is that which always maintain wires in parallel to the track and to provide the current collectors with constant reaction force. Installation of overhead contact wires must be accurate as much as practically for high speed trains, otherwise much damage will be made to overhead contact wires and current collectors by arc generated between wires and collectors. As the maximum speed is expected to be 90 to 100 kilometers per hour in the case of the metropolitan rapid transit railways of Teheran, suspension of overhead lines should be by the simple catenary method, in which the overhead contact wires are suspended

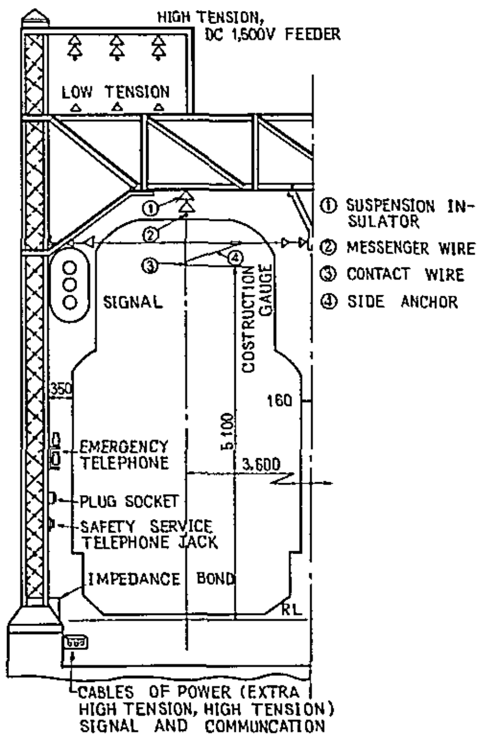


Fig. 4-6-20 Overhead contact system catenary suspension system

by hunger from messenger wire (zinc galvanized steel stranded wires having a cross-sectional area of 90 square millimeters) attached to the supporting structure by suspension insulator and tensioned horizontally. (Refer to Fig. 4-6-20.) In this case, tensioning devices to be provided should provide automatic tension adjustment in view of the climate of Teheran where the fluctuation of temperature is high.

For the underground section of the railway, special considerations must be given for the prevention of drooping of severed overhead contact wires to prevent the occurrence of serious accidents and for the reduction of the length of line suspenders in view of reduced cross-sectional area of tunnels from economical reasons.

Overhead contact wires of various types have been developed in Japan for this purpose. Figure 4-6-21 and 4-6-23 show an example of these types. T bars (aluminum, 1900 square millimeters) are employed in place of messenger wires and hungers of the catenary method, and overhead lines are fixed to T bars with short interval.

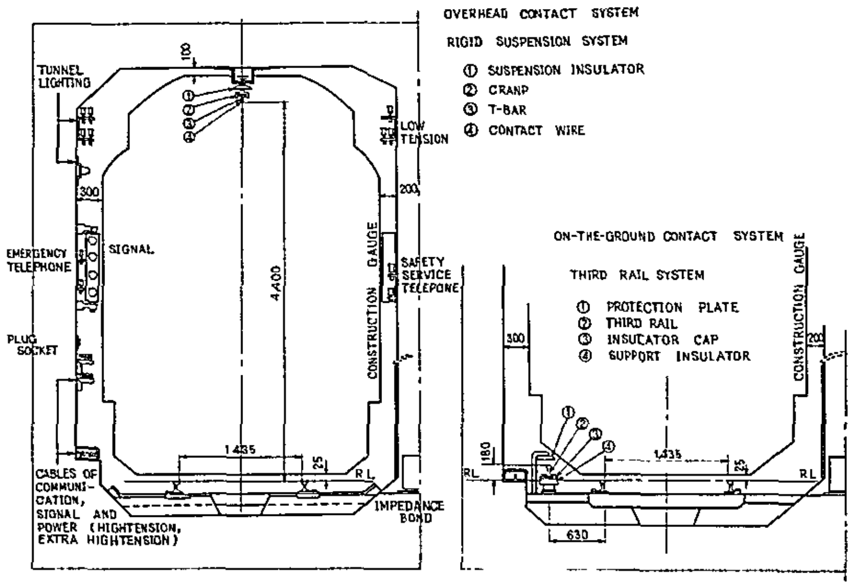


Fig. 4-6-21 Contact System

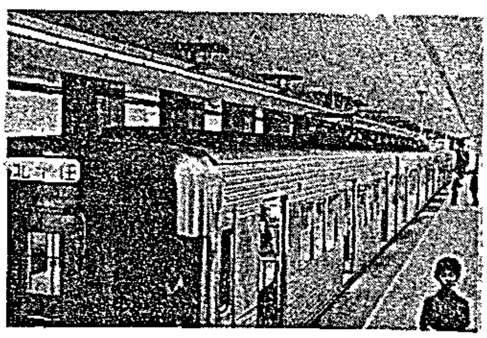


Fig. 4-6-23 Rigid suspension system

The distance required between the folded current collectors of the train and the overhead contact wires is 400 mm ordinarily for the overhead contact lines system. However, it has been proved that this length could be shortened to 250 millimeters if appropriate protective devices are provided to immediately suspend the supply of power to the affected section in case of any electric accidents. Overhead contact wires, along with the feeder which is connected parallel to the wires, must be separated electrically at appropriate places such as substations or railway stations in order to detect electric accidents and to prevent spread of confusion in case of emergencies (Refer to Fig. 4-6-18).

(B) Return Circuit

As previously discussed in 6.7.1.(C), it will be more economical to utilize rail track for the return circuit (Negative circuit) (refer to Fig. 4-6-18). In this case, rail bonds (Two or more bare stranded copper wires, each having a cross-sectional area of 200 square millimeters) must be connected parallel to the joint of rails where electric resistance is high. Attention must be paid to the fact that the high resistance of the return circuit causes accelerated leakage of current from the rail to the ground, resulting in corrosion of underground metallic structure in its vicinity.

(C) Feeder

As the overhead contact wire has a small electric capacity and large electric resistance because of its small section area, transmission of large load current with this line alone over a long distance is extremely difficult. For this reason, the section required large load current must be provided with feeder line stretched along the overhead contact wires and connected to them in parallel.

The diameter and number of live of the feeder vary depending on the load current, but one or two lives of aluminum stranded wires of 500 square millimeters or copper stranded wire of 325 square millimeters are mostly in use.

A circuit breaker must be provided for the outlet of the feeder at the substation to protect equipment in the substation against overcurrent. (Refer to Fig. 4-6-19.)

4.6.7.4 Auxiliary Equipment

(A) Auxiliary Equipment

In the railway system such auxiliary equipment as power rail switches and signal warning devices for safe operation of trains, illumination equipment for station buildings and tunnels, heating appliances, signs, drain pumps, ventilation and exhaust fans and escalators are required in addition to the electric equipment needed only for physical movement (operation) of train.

The economic burden of these auxiliary equipment becomes much heavier with underground structure than with the above-ground or elevated structure.

(B) Distribution Lines

The power received by the railway substation is transformed to 6 kilovolt by transflrmers provided specially for auxiliary equipment and distributed to the switch house of each station through a distribution line breaker and distribution lines installed along railways. Two circuits must be provided for distribution line, one for essential load such as signals and pump rooms and the other for ordinary load such as lighting and heating (Refer to Fig. 4-6-18).

Distribution line is to be of cable for the underground structures and either overhead line or cable for the ground (above-ground) and elevated structures.

(C) Transformers

The capacity of a transformer for auxiliary equipment in the railway substation varies depending on the required load, but one transformer having a acpacity of approximately 2000 to 3000 kilovolt-ampere for every 3 or 4 substations will be sufficient for underground structures. (Refer to Figs. 4-6-18 and 4-6-19). The power distributed in 6 kilovolt must be reduced to 400 or 200 volt at the switch house of each railway station and supplied directly to auxiliary equipment through interior wiring system. In this case, the required capacity of transformers in the switch house will be as follows:

Switch house	Capacity (kilovolt ampere)
Small scale subway	250
Large scale subway	600
Car shed	300 to 500
Car workshop	1,000 to 2,000

(D) Measures against Power Failure

Stoppage of power supply to such auxiliary equipment as illumination and signal facilities results in great confusions in the railway especially in the case of underground structure. Therefore, special precautions must be taken for the prevention of power failure for such essential equipment as signals, emergency lights and pump rooms (Refer to Fig. 4-6-18). The following precautionary measures may be cited as examples.

(1) Two circuits of distribution line are to be provided and the power supply to essential equipment is to be made through an automatic change-over switch.

(2) Spare transformers are to be provided for essential equipment.

(3) An emergency diesel engine generator (about 500 to 700 kilovolt ampere per line) is to be provided against power failure at the receiving side.

(4) Storage batteries are to be provided as a D.C. power source for emergency lights and signals.

4.6.8 Signal and Communication Systems

(1) Signals and Safety System

(A) Blocking Devices

In order to secure safe train operation, railway lines must be divided into some blocks (closed blocks). Trains must proceed into the block after ascertaining that no other trains exist in the block and that it is safe to enter the closed block. Movement of trains must be made only on the repetition of the above procedures. The method used for the confirmation of safety for entering the closed blocks include tablet and ticket block system, tablet block system and automatic block system.

For the railway of high speed and high density of train operation like the Metropolitan rapid transit railways, automatic blocking system must be adopted as a matter of course. (Refer to Fig. 4-6-24).

The automatic blocking system which utilizes running rails as a signal circuit for the device which automatically detect the train in the closed block provides continuous detection and is highly dependable. Besides, there is a system in which detection devices are installed only at both ends of a block to detect the movement of the train at one point. For the train having rubber tires, only the latter may be used.

(B) (Railway) Switches

Switches which are in constant use must be all power switch machines operated by remote control system. The power switch machine has two types, the one which operates on electric motor and the other by compressed air through a solenoid valve. Either of them may be used, but the latter which is less susceptible to humidiy and inundation is considered more suitable for the underground section than the former.

(C) Signals

Signals must be installed at the starting point of the block to which the train proceeds. The type of signal to be installed must be that which is able to give a signal to the train to proceed only when the opening direction of the switch in the block is normal and no train exists within the block. The signal to be used for automatic block system must, of course, be a color lamped signal which operates automatically.

The indication system of signal varies depending on how many intermediate signals are to be provided between stop signal (R) and all clear signal (as a standard), but one warning signal is considered sufficient in view of the planned train speed, operation density and also from economical aspect.

The automatic block system and the automatic signal system are designed in one unit as the automatic block signal system, but the signal at the station (especially where shifting of switch is required) must be of the type which is able to give a stop signal at the will of the signal man. (Refer to Fig. 4-6-24.) In recent years, signals are often installed in the motorman's cab instead of the ground as seen in the trains on the New Tokaido Lines of the National Railways, subways and monorail in Japan. Installation of signals in the train is easily accomplished for the train adopting electric system for automatic train stop device described in 6.8, 1.5 and offers easier confirmation of signal than that on the ground.

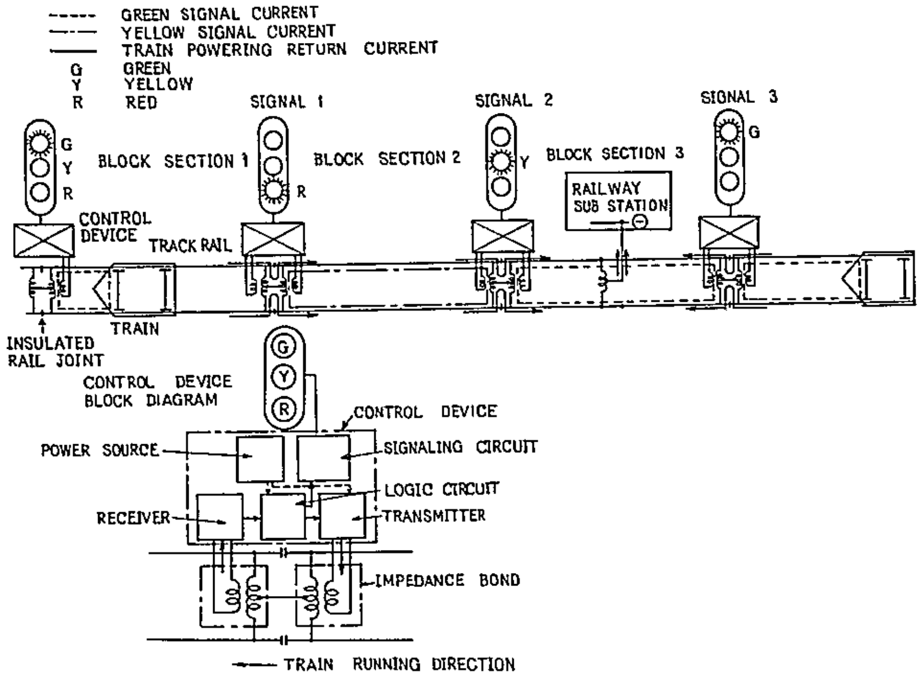


Fig. 4-6-24 Automatic block signal system

(D) Interlocking Devices

It will be extremely dangerous if any switch in the block operates inadvertently while an all clear signal is given. Increase of the number of signals and switches results the increase of the possibility of mishandling of these equipment. Therefore, to prevent this possibility, there must be an interlocking devices provided between the related signals and switches, which control both the signals and switches in conjunction with the movement of trains.

The type of interlocking devices is mechanical type, electric-mechanical type, electric type or relay type. For the automatic block signal system, the relay type must be used as seen at the Teheran station of the State Railways.

(E) Automatic Train Stop Device

When the motorman fails to take proper procedures in response to the indicated signal, particularly when he fails to stop his train at the stop signal before the train comes to the signal, there is high possibility of an accident. compared with other types of railway, accidents in the subway and monorail system are expected to cause far heavier damages. Therefore it is necessary to provide a device which automatically stops train not to pass the stop signal due to the negligence of motorman. In view of the fact that the Teheran Metropolitan Rapid Transit Railway network involves steep sloped section, this device is considered indispensable.

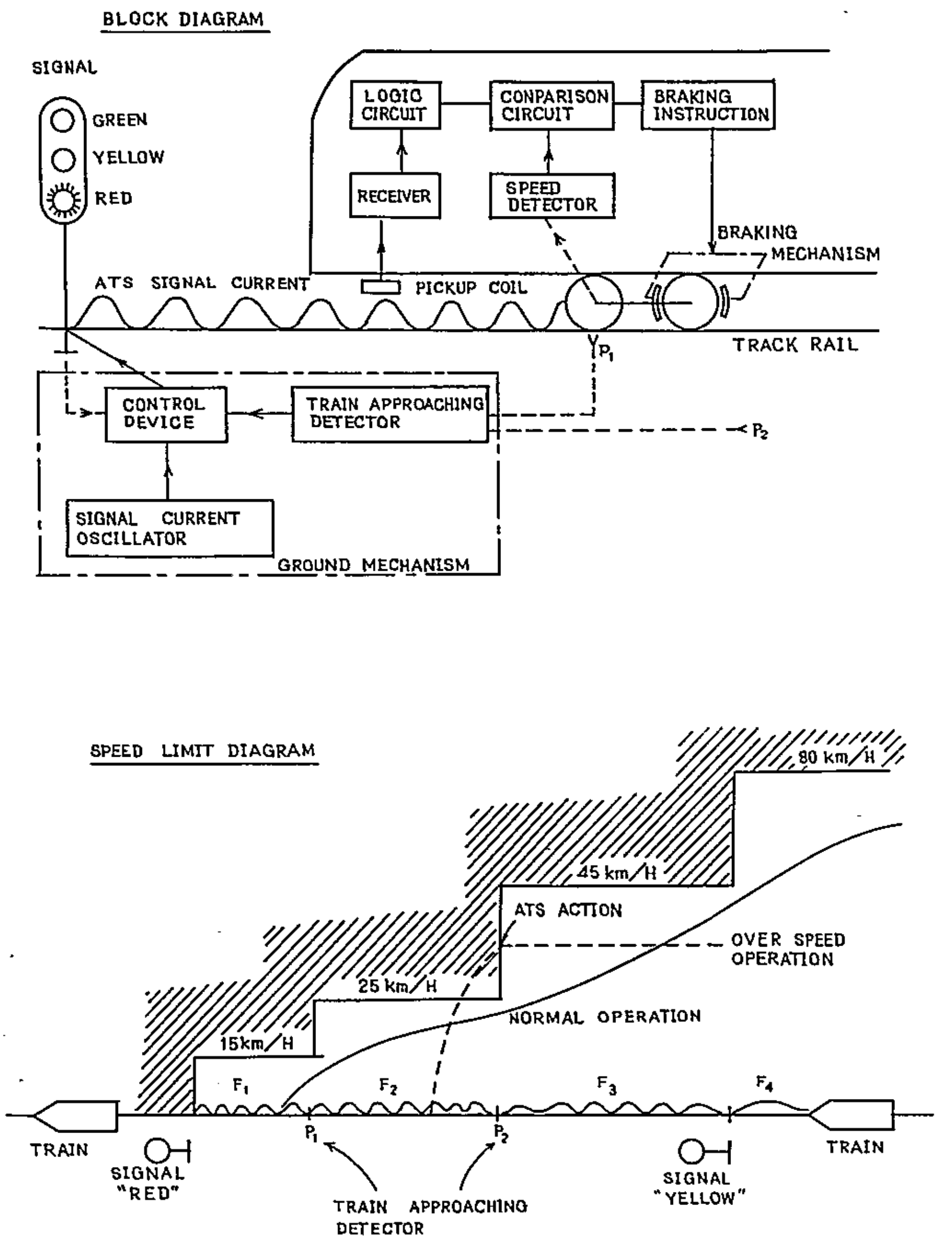


Fig. 4-6-25 Automatic train control

The type of automatic train stop device is the mechanical type or electrical type. In this case, however, the electric type is more desirable for that automatic control system and automatic operation system could be added to it in the future. Fig. 4-6-25 shows an example of the electric type.

When the train approaches a stop signal, this device detects the arrival of the train at a certain point and sends to the rail of train running a signal indicating the speed limit according to the location of the train. On the train, meanwhile, this information is received and compared with the speed of thettrain, and the control system operates automatically to reduce the speed when it is higher than the speed limit.

As the reliability of the safety device is higher than that of manual, the train operation system should be gradually changed to automatic from manual. In this connection, installation of automatic train control system which controls the speed of a train automatically in accordance with the indication of signal is desirable if economically permissible.

(F) Centralized Traffic Control System

Operation of signals and switches is handled by operators at each station. It is desirable, however, that a system (CTC device) which operates and observes signals and switches at each station through the remote control surveillance device is provided by consolidating signal stations of one line to one place (operation control center) in order to provide a constant survaillance over the train operation for the entire line, to take effective measures in case of suspension of train operation and to minimize the number of signal operators. In this case, it will be more effective if a device which is able to indicate the position and the number of running trains is employed as an auxiliary device along with the above device. Fig. 4-6-26 and 4-6-27 show examples of operation control center equipped with CTC control device, train number display panel and operation instruction telephones.

In Japan even the operation of CTC is automated by attaching electronic computers to the device for the section where density of train operation is high and many types of train are in service.

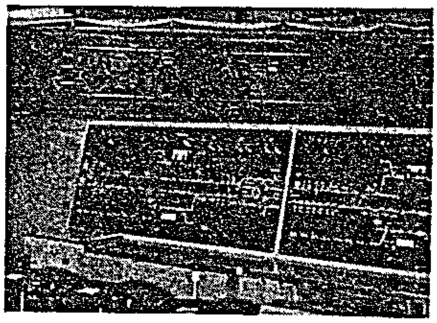


Fig. 4-6-26 Train operation center (C.T.C. Control board)

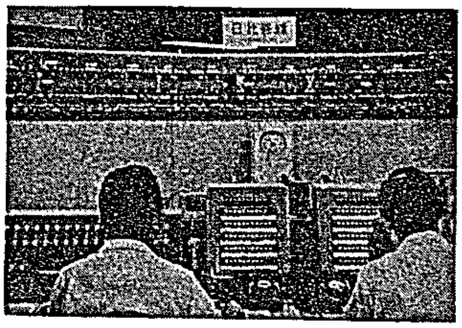


Fig. 4-6-27 Train operation center (Train dispatching radio)

(2) Communication Equipment

In Japan operation of train is very punctual and time-checks of the train operation are made in the unit of second at such major points as train stations. As the result, the railway in Japan has won the trust of the general public. For accurate and systematic operation of trains, there must be a complete communication system behind the scene.

The communication system must have a separate circuit for each purpose so as to provide rapid and accurate communication even in an emergency. Shown below are the communication circuits required for each train section of the metropolitan rapid transit railways.

Description	Purpose	Location	Main Equipment
Operation instruction circuit	Operation control Notification of accidents, Emergency instructions	Operation control center, Major stations, Signal stations, Car shed, Power control center	Operation instruction telephone 100 circuits
Power instruction circuit	Power control, emergency instruction for power failure	Power control center Substations, Power section office, Operation control center	Power instruction telephone 20 circuits
General purpose circuit	Communication of general railway services	Main office, Stations (Administration, Booking office, Public address system) and each field office	Automatic telephone switchboard 200 circuits
Circuits for field works	Communication for field work such as maintenance of rails and signal	Portable	Link or plug-in type 1 circuit
In-station circuits	Communication for dispatching trains and other in-station coordination	Car shed, Workshop, Major train stations	1 circuit each
Emergency telephone	Communication between operation control center, Power control center and trains	Operation control center, Power control center, Trains	Inductive radio or space radio

In case of an urgent request from a train for immediate suspension of power supply, notification should be made directly by means of code instead of voice through emergency telephone circuit.

As for the type of installation of communication lines, emergency telephone circuits and field work circuits should be of suspension type and the other circuit of telephone lines should be of communication cable type which must be placed in the trough provided along the rail.

For the circuits for field work, either bare wires should be used or terminals should be provided at an appropriate intervals on the circuit so that a portable telephone can be hooked to them.

4.6.9 Rolling stocks and Maintenance Facilities

4.6.9.1 Rolling Stocks

(A) Basic Concept

As already suggested, the basic concept of structure and performance of rolling stocks to be adopted for the Metropolitan Rapid Transit Railways calls for electric car as the type of cars, D.C. 1,500 volts as the type of electric system and roof pantograph collector as the type of current collector.

In addition to the general requirement that the structure of rolling stocks should be adequately able to stand the travelling from the standpoint of theory of structures, special attention must be given to the following points.

(1) To increase schedule speed:

a. Acceleration, deceleration and average speed must be increased by the increase of power against the weight of a train.

b. A reduction of stoppage-time must be planned by proper arrangement of train door so as to accelerate loading and unloading of passengers.

(2) To secure safety of train:

a. Materials to be used for train cars must be non-combustible or incombustible for fire prevention and protection.

b. Automatic train stop devices must be installed in the train to prevent the possibility of collision.

c. A corridor must be provided in the train so that passengers are able to move from one coach to another.

d. There must be a means of communication between passengers, train crew and operation center in case of an emergency.

e. Required equipment must be equipped with instruments and indication lights to show their operating conditions.

(3) To provide better service:

a. The size of a coach must be as large as permissible.

b. Comfort of passengers must be taken into consideration in respect to ventilation, heating and sound proofing.

c. Public address system must be provided for the convenience of passengers.

d. Emergency lights must be provided against power failure.

(4) To save power energy the car body and bogie truck must be made lighter, and the bearing to be used must be ball bearings.

(5) To simplify electric train control system:

a. A multiple unit control system must be employed as a train control system.

b. Train operation must be simplified.

c. Simplification of operating devices must also be considered.

(6) Sealing of electrical system and air brake system must be given special attention for the protection of equipment from dust.

(7) Full consideration must be given to the expansion and contraction of metals, the conditions of oils, fats and electronic appliances such as transistors in use, and the deterioration of organic materials in view of large fluctuations of the temperature.

(8) All cars to be installed must be electric motor cars to ensure easy operation of train.

(9) To simplify maintenance of cars:

a. Structure of train cars must be as simple and durable as possible, and unnecessarily delicate design must be avoided.

b. Maintenance-free operation of cars must be planned by adopting ball bearings for axle bearing and employing non-contact system for electric contact and eliminating painting of car bodies.

(10) As the Metropolitan Rapid Transit Railway of Teheran has steep slope section in its project route, a full consideration must be given to the gradient of the route.

a. Relation between the gradient and acceleration

If the gradient of the railway line is to be expressed by tan θ, acceleration by A (Kilometer per hour per second), running resistance by γ (Kilogram per ton) and the coefficient of adhesion between the rail and the wheel by α, the following expression may be developed theoretically.

$$10^3 \tan \theta \doteqdot 10^3 \alpha - (31 A + \gamma)$$

Provided the wheel is made of steel α will be 0.3~0.35 when the surface of the rail is dry, 0.2~0.25 when the rail is wet by rain and 0.1~0.15 when the rail is covered with sleet or frost.

A train running at a uniform speed can ascend the slope up to 95‰ even when α is 0.1. The Hakone-Tozan Railway (mountain railway of the Mount. Hakone) in Japan has the section with the maximum gradient of 80‰.

When the train accelerates its speed at a grade section, the upper limit of the slope which the train can ascend varies greatly depending on α and A.

Under normal operating conditions, however, the train is to accelerate its speed within station area (to be designed with the grade held below 10‰ or at the gently sloped section, and is not to accelerate its speed at the steepest section.

When it is necessary to make an unscheduled stop at the section of steep slope, start should be made by reducing acceleration.

b. Capacity of driving motors

For the capacity of driving motors to be equipped on the cars of the Teheran Metropolitan Rapid Transit Railways, such severe conditions for motors as required for sufficient traction force to maintain high constant schedule speed even at the grade section and long powering and electrically braking hour must be taken into consideration. It is recommended, therefore, that every car is equipped with four 100 KW motors.

For the control of motors, caution must be taken not to cause a sudden change of acceleration and deceleration in order to prevent slipping or skidding of wheels.

c. Brake equipment

Special attention must be paid to the design of brakes of the train because in the grade section, descending is more dangerous than ascending.

In descending a long slope the train must fully utilize its electric brake just as an automobile uses its engine brake, and at the same time, the design of brakes must be made to provide sufficient large capacity.

Braking force is applied to the train when the driving motor is switched over to the generator to convert the kinetic energy of the train to the electric power energy, and the generated power energy is consumed for the purpose other than driving the train. In this electric brake, the method in which generated power energy is consumed by the rheostat of train in the thermal energy is called the "Dynamic braking", and the method in which generated power is returned to other trains or substation in its vicinity through overhead contact wires is called "Regenerative braking".

In the case of the regenrative braking it is advantageous that the train itself does not generate heat. But on the other hand, it is disadvantageous that there must always be other electric trains or substation to consume its generated power and that it is difficult to send back power from the receiving point to the power source unless the rectifier is a rotary type. In the case of dynamic braking, the advantage and disadvantage are reversed.

Under normal conditions, the majority of trains employ the generating brake. However, for the train of subways which have many grade sections, the device which utilizes advantageous features of both systems is also conceivable in addition to the generating brake.

As the electric braking cannot be applied when the train is running at an extremely high or low speed or when making a stop, ordinary pneumatic brake must be provided as a braking device for this range, as a matter of course. Both the electric braking device and pneumatic braking device must be of the type which requires simple operation.

No sand strewing device or special braking device will be required for the slope of about 50‰ gradient.

(B) Rolling Stock Gauge and Other Basic Dimensions

The rolling stock gauge is shown in Fig. 4-6-1 and the size of a car must conform with this limit. There must be a certain clearance between the rolling stock gauge and the construction gauge to allow for the swing of car, and a clearance of at least 200 millimeters is required at both sides and a clearance of 50 mm for the lower portion.

As for the basic dimensions in relation to the ground facilities, the length of a car is to be 18 meters between coupling faces, and the truck is to be of the bogie type with rigid wheel base of 2.2 meters, bogie center distance of 12 meters and wheels in a diameter of 0.86 meter. The height of floor is to be 1.06 meters from the surface of the running rail.

(C) Structure and Performance of Rolling Stock

(1) Type: Metallic, double-axle bogie truck, motorized car

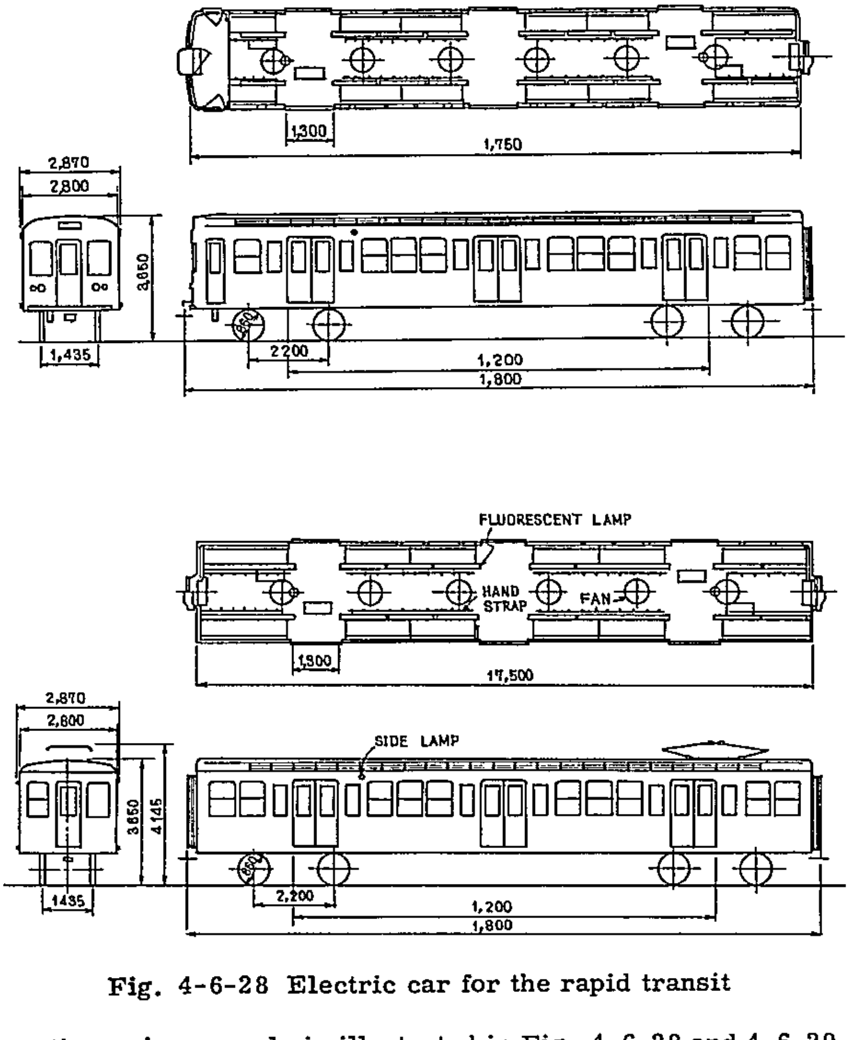


Fig. 4-6-28 Electric car for the rapid transit

(2) Configuration: An example is illustrated in Fig. 4-6-28 and 4-6-29.

(3) Track Gauge: 1.435-meter is to be adopted in view of possible mutual train operation service with the State Railway line.

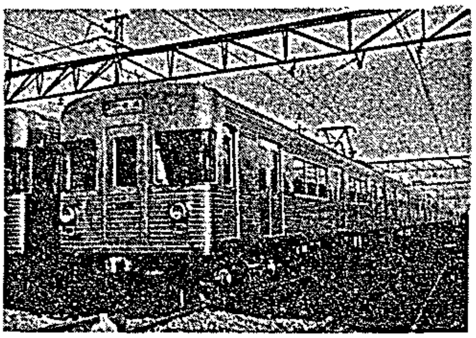


Fig. 4-6-29 A train for the Rapid Transit

(4) Electric System: D.C. 1,500 volts, roof pantograph current collector system

(5) Tare Weight: Approximately 33 tons per car

(6) Loading Capacity: 150 (total of seating and standing capacities) per car

(7) Floor Space per Person: Approximately 0.3 square meter

(8) Maximum Dimensions:

a. Length (between coupling faces): 18 meters

b. Width (between side panels of the body): 2.8 meters
(between indication lights): 2.88 meters

c. Height (height of current collector when folded):
4.15 meters above the surface of the rail

(without current collector): 3.68 meters

(9) Distance between the Centers of Bogie Trucks in a Train: 12 meters

(10) Rigid Wheel Base of Bogie: 2.2 meters

(11) Diameter of a Wheel: 0.86 meters

(12) Height of Floor: 1.06 meters

(13) Structure of Car Body

All metallics welded structure with service life of 20 to 30 years. Devices to be installed on the roof such as current collectors must be double-insulated electrically. It is desirable that the roof and exterior board are lined with sound-arresting and heat insulating materials. Use of stainless steel or aluminum alloy for exterior panels and corrosion resisting metal sheet for interior finish and aluminum sashes for window frames will eliminate the requirement for paint job and will be more economical.

(14) Car Door

Three doors are to be provided on each side. They are to be all double doors. They must be automatic door which operate simultaneously on all cars. Indication lamps must be provided on the side of the car to show the opening and closing operation of doors and interlocking devices which prevent the train from starting until all the doors are closed must be provided as a safety precaution.

(15) Corridor:

Corridor must be as wide as possible and must be enveloped with bellow type hoods to protect passengers from dangers.

(16) Window

In the case of underground railways with a very small clearance between the car gauge and the construction gauge, the height to which the window can be raised must be restricted so as to prevent passengers from leaning out of the window.

(17) Floor

Keystone plate must be welded to the surface of underframe and cushions of greater sound-arresting abilities must be stuffed to prevent noise from a part under the floor.

(18) Seat

Long seats must be used for commuting trains to increase seating capacity. Material of seat must be of incombustible type. Consideration must also be given to the arrangement of handrails for standing space because of high acceleration and deceleration of speed and of high loading efficiency of the commuting train.

(19) Structure of truck

Structure of truck must be of double-axle bogie and of welded structure to make the weight of truck lighter.

(20) Wheel

In view of steep slope in the project route, use of no tire type of solid rolled wheel will be much safer than the use of tire type wheel. Bearings to be used should be ball bearings.

(21) Spring Buffer

Under normal condition, one spring buffer is provided between truck frame and wheel shaft, and another between truck frame and car body.

Metallic coil spring may be used in both cases, but use of air cushion for the latter is increasing in Japan. The air cushion provides soft feeling but requires an additional device to supply air to the air bellows.

(22) Car Coupler

Car coupler to be used must be of one touch automatic coupler type. In view of the fact that every car in this case has its own motors unlike the car towed by a locomotive, the car coupler should be of close contact type free from vibration and noise, and should be of so convenient design as to provide mechanical coupling of cars and also connect braking and electric systems simultaneously.

(23) Current Collector

Movable parts of current collector should be made light in weight and should be designed to maintain uniform upward force so that the current collector makes a close contact with overhead contact wires while running. For the part of the current collector piece which makes direct contact with overhead contact wires, such materials as copper, carbon or sintered alloy slide plate is suitable for sliding and current collecting.

(24) Traction Motor

As for traction motors, four sets of DC series motor (375 volts, 100 kilowatts, each), which is most suitable for the characteristics of kinetic dynamics, are to be provided for each car. When installing motors on the truck, consideration must be given so that the axle load will not be burdened by motor.

(25) Transmission Devices

Because of reciprocal motion caused by vibration of axle between the motor and axle gear, the output axle of motor and the input axle of transmission gears must be linked with a special universal joint.

(26) Control System

Control system to be provided must be of multiple-unit control system in which the main controller of each car which switches on and off the current directly in each car is controlled indirectly by one master controller.

The master controller is to be equipped in the car used as the lead-off car, and it will be economical to provide one main controller for every two cars to control eight motors on the two cars. Therefore, cars are used as a unit of two.

To prevent slippage of wheels, special consideration must be given to the speed control of motor so as to obtain smooth acceleration and deceleration, and at the same time, a slip detection device must be provided. Also, from the standpoint of the easier operation of the car, consideration must be given by providing automatic acceleration system for power running and self-lap system (braking force selection system) for braking and at the same time by providing load compensation mechanism for both of them so as to make the motorman have the same feeling while operating the car whether the car is packed or empty.

(27) As discussed previously in 4.6.9.1 (A)(10) c., a careful attention must be paid to braking device of car used for grade section.

Electric braking device and pneumatic braking device must be of a convenient type for operation, which will interact and provide appropriate braking force upon the instruction from a single control lever.

(28) Instruments and Indication Lights

These are to indicate the operating conditions of required devices and they must be installed at the location to which crew members have an easy access for confirmation.

(29) Automatic train stop device and operation instruction communicating device (emergency telephone) must be of the type which can withstand severe conditions such as extreme temperature and vibration as mentioned in 4.6.8 (1) (E) and 4.6.8 (2).

(30) Others

Other auxiliary equipment required are lighting, ventilation, heating equipment and announcement system in the car. For the power source of the above equipment, motor-generators, inverters and storage batteries will be needed.

In general the structure and the performance of a car vary depending on the track alignment to which the car is assigned. If the car is not to be used at grade section, the capacity of its motors has not to be large and the car which is not to be used at the section of small curve radius in the heart of the city can be a long one.

(31) Operation Performance

Acceleration is to be 4 kilometers per hour per second. Deceleration is to be 4 kilometers (4.5 kilometers in case of an emergency) per hour per second. The maximum speed is to be 110 kilometers per hour.

4.6.9.2 Inspection and Maintenance Facilities

(A) -Car Inspection and Maintenance System

Cars must be inspected periodically and repaired immediately when faults are found, for the prevention of accidents and for their economical use.

The frequency of car inspections varies with the mechanism, parts and the type of inspections to be made. Types of inspection to be made are daily, monthly, annual and every three years inspection and overhaul inspection.

Daily inspection is an overall inspection made every day before the start of the operation. Monthly inspection is performed once every month on the essential portion of the car. Annual inspection is performed once a year and essential portions of the car are disassembled and closely inspected. The every three years inspection is the inspection on overall portion of the car disassembled once every three years. Overhaul is performed every ten years and it is a thorough repairs in which all riggings are renewed and repaired to make the car almost new.

If the number of days during which the car is kept in the shop is shown by Si, the number of cars kept in the shop during that period by ni, spection which is shown by the number of days by Di, the number of cars n, which are kept in the shop for all types of inspection may be calculated by the following formula.

$$n = \Sigma n_i = (\Sigma \frac{S_i}{D_i}) \cdot N$$

In order to carry out smooth inspection and maintenance, extra cars must be provided for troubling in addition to the cars in the shop expressed by n in the above formula beside the number required for operation.

(B) Car Shed

Main functions of the car shed are:

(1) Parking of cars
(2) Dispatching of cars (Formation of trains)
(3) Cleaning and inspection of cars

Besides the daily and monthly inspections mentioned in 4. 6. 9. 2 (A), unscheduled minor repair works are also performed here.

For the accomplishment of these functions, such facilities as the parking line, car washing line, daily inspection spot and monthly inspection spot are also necessary besides the office room. Also, such machines as the car wheel grinding machine, boring machine, grinding machine, welding machine, air compressor and lifting jack, which are necessary for inspection and maintenance of cars, must be provided.

Though the assignment of car sheds to each operating line may be desirable for efficient operation of cars, its arrangement must be reasonably centralized by taking into consideration the condition of lines and the number of cars for efficiency operation from an economical point of view. A branch of car shed will be needed for the station where trains are coupled and separated or where arrival and departure of trains are frequent.

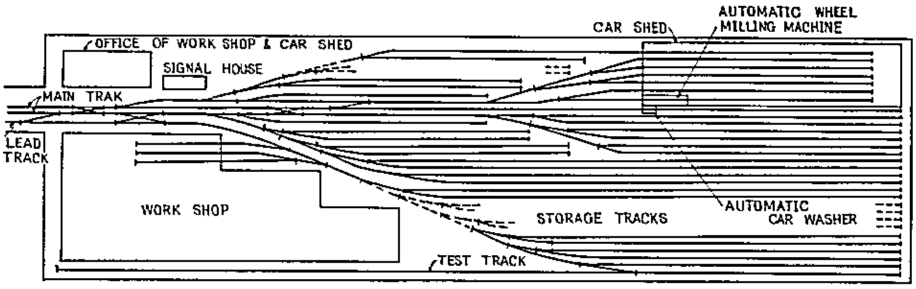


Fig. 4-6-30 A layout of car shed and workshop

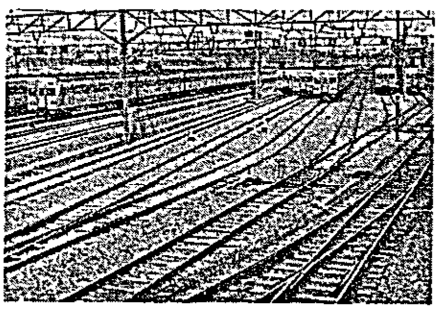


Fig. 4-6-31 Car shed and workshop

When the construction of a car workshop is planned in the neighborhood of proposed site of car shed, it will be more economical to plan a rolling stock base by integrating them into a single site. Fig. 4-6-30 and 4-6-31 show an example of such arrangement. For the Teheran Metropolitan Rapid Transit Railways, the car shed is to be provided on the same compound as the workshop. For the number of car sheds to be built, there will be one car shed (three lines are required for daily inspection and 2 lines for monthly inspection) for about 400 cars of No. 1 and 2 lines and another for 600 cars of No. 3 and 4 lines (four lines for daily inspection and three lines for monthly inspection).

When the arrangement of car shed is centralized to a certain extent in this way, installation of connecting lines between the related line sections must be considered to forward cars. In the case of No. 3 and 4 lines, connecting lines will be provided without too much difficulty at the section where two lines parallel to one another in the western part of Teheran. For No. 1 and 2 lines, however, the situation is rather complicated. In this case, plans must be worked out to provide a connection line between the two railway lines or between the railway lines and car shed, by providing a line at the point where two lines cross each other or arranging the operation of car directly into the State Railways which has been improved and electrified as urban railways, as mentioned in the section dealing with the improvement of the State Railways.

(C) Car Workshop

In the workshop, cars are disassembled and given a close inspection and maintenance. Beside annual inspection, every three years inspection and overhaul of cars, the maintenance shop also provides unscheduled major repair works.

For the accomplishment of these functions, the following facilities are required in addition to the office room:

Entry inspection spot, disassembly and rigging shop, car body shop, paint shop, truck shop, wheel shop, rotating machine shop, electric parts shop, pneumatic parts shop, machine tools shop, warehouse, power room, boiler room, air compressor room, parking track and test track.

Machines, equipment and tools required for shop works are as follows:

Machine tools such as lathe of various types, boring machine, milling machine, shaping machine, grinding machine, car wheel grinding machine, car wheel lathe and axle press

Transport equipment such as crane, hoist, lifting jack, and cart

Test equipment such as ultrasonic shaft flaw detector, magnetic flaw detector, rotary tester, pneumatic braking device testing table, conversion load testing device, dielectric strength testing machine, and relay testing table. Other equipments include truck washer, washer for various parts, paint shop equipment, dust arrestor, electric dry furnace, welding machine and so on.

It will be more economical to plan centralization of car workshop as much as possible because the shop requires many equipment of various types for inspection and maintenance. It is considered most appropriate for the Teheran Metropolitan Rapid Transit Railways to provide its maintenance shops on the same compound as the car shed and to plan procurement of land space for this purpose in the south of Teheran for No. 1 and 2 lines and also in the west of Teheran for No. 3 and 4 lines.

The size of car shed and car workshop to be provided should not be less than the following.

	Total Number of cars (car)	Total land area (m^2)	Total floor area (m^2)
No. 1 and 2 lines	395	100,000	16,000
No. 3 and 4 lines	618	150,000	25,000

4.6.10 Order of priority on construction work and construction period

(1) Order of priority on construction work

As stated previously, the construction of a rapid transit system has been recommended for this city. Here a study will be made to decide on which route the work should be started first.

The order of priority in construction is generally determined after weighing the intensity of need, the relative difficulty of the construction work and the effect of the line after commencing operations. In other words:

(A) Work should begin in a section where the high speed mass transportation of passengers, the object of the urban transit system, may be realized to the maximum extent.

(B) Sections affording a greater alleviation of surface traffic, which is also the object of urban rail transit, should be begun early.

(C) Though the route is often divided into sections for construction purposes, a car shed and maintenance shop need to have been completed prior to operating.

(D) The route to be constructed must include busy sections and must have sufficient length to obtain expected operating revenue. The route must pass through the center of the city and it must have a length of at lease 5 km.

(E) It is advisable to begin with a section where construction work involves less difficulty.

When a comparison of all the proposed routes is made on the basis of the above requirements, it is considered best to start the work with No. 1 line. In Teheran people are not accustomed to use railways for commuting and as a result, compared with other cities, it is rather difficult to estimate the number of passengers who would shift to the railway from their present practice of walking, riding buses or driving their own cars. It will be a fairly long time before the public starts realizing the utility value of the railway and get accustomed to taking the train. For this reason, the construction of a section, where the use of the train by many people is expected to be high, will be a prerequisite to the completion of the transit networks.

As the simultaneous starting of construction work over the entire length of No. 1 line may be difficult, the route will probably be divided into sections. If a division is made, it will be most advisable to start the work at Teheran Central Station on the State Railways. Work on the road in front of the station is considered relatively easy judging from the width and traffic conditions of the road. Also, because of its proximity to the center of the city, this section is considered to have high utility value. Meanwhile, the rolling stock shed and maintenance shops required for operating the line are also expected to be located near the State Railways.

In view of the above fact, it is considered very effective to construct the section between Teheran Central Station on the State Railways and

Abbass-Abad, a total length of 11.5 km, and inaugurate the first phase of operations with these stations as terminals, and then plan the future extension from these terminals.

Then the work should start with No. 2 line which cuts through the present downtown area from east to west. For the first phase, the line originate in Mehrabad airport, pass through Shah Street and Nadeki Street, and extend through Emamiyen to Teheran-now or Narmak. The terminal station provided in the vicinity of the airport at the west end of the line may be connected to the industrial area by bus. The terminal for the east end is to be located in Narmak.

With the completion of this section, road traffic in Shahreza, Mehran, Shab and Naderi streets and other downtown areas will be alleviated considerably. In the second phase the line may be extended to the west depending on the progress in the improvement of the State Railway and the east end of the line may be extended to Teheran-Pars.

For the No. 3 line, the western terminal should be located in or around Hasan-Abad, and the section including Amirabad and Sepah street up to Soleymaniyeh should be completed during the first phase. Extension beyond Hasad-Abad may be made as required.

The No. 4 line will be the last of all the lines. It will be sufficient to complete this line in time for the full-fledged operation of the administrative center in Abbas-Abad. Until that time the No. 1 line will be used to reach Abbas-Abad.

(2) Construction time

The greater part of the subway tunnels recommended for Teheran City are box section tunnels which are built by the open-cut method in which the ground is excavated from the surface and filled in after the completion of the tunnel. As it is possible with this method to start the work along the entire length simultaneously, the route should be divided into sections, each having a length of 500-1000 m, so that the work may progress with efficiency while maintaining a reasonable working scale. In this way the work on the entire line may be started simultaneously, to enable the inauguration of the entire line simultaneously. In Tokyo the construction of one section having a total length of 500-1000 m requires 24 to 30 months. Any section involving particular difficulties is further divided into subsections each having a total length of about 300 m so that the completion of such sections may take about the same time as the other sections. Because of favorable soil conditions in this city, the construction time is expected to be much shorter than that in Tokyo. As the construction of power facilities, car sheds and tracks and interior finishings of the stations may be completed in 24 to 30 months, a construction period of 36 months (3 years) allowing for the training of motormen may be appropriate.

4.6.11 Estimated construction costs

The estimate of the construction costs was reached by dividing the total cost into civil work, buildings, track structure, electrical equipment, car sheds, rolling stock and management costs. (Table 4-6-6). As none of these divisions are not yet in the phase of detailed engineering, the estimate was made in the following way.

Cost of civil works:

Calculation was made separately for the open-cut method, the shield tunneling method and the elevated structures. With the open-cut method, the depth of excavation greatly influences the construction costs and therefore, the quantity of soil excavated was calculated for each route on the basis of its profile.

Table 4-6-5 Cost of civil structural works

Unit: million Rials

	Open cut (Box section tunnel)	Shield (Shield tunnel)	Elevated structures	Total
Route No. 1	6,400 (330)*			6,400 (330)*
Route No. 2	4,080 (280)*	940 (270)*	350 (86)*	5,370 (232)*
Route No. 3	3,420 (270)*		1,610 (82)*	5,030 (156)*
Route No. 4	3,070 (240)*		2,060 (84)*	5,130 (138)*
Total	16,070 (280)*	940 (270)*	4,020 (84)*	21,930 (196)*

note: * Construction cost per km.

Though the need for sheathing and timbering in excavation work is usually determined by soil conditions and the possibility of spring water, this estimate assumed that the soil conditions in general are so favorable that there is no need for timbering and that the possibility of spring water is eliminated. Under these favorable conditions, the estimate of the construction costs assumed the use of construction equipment which is not only advantageous economically but in terms of construction time as well.

When using the open cut method on a road it is necessary to provide planking in order to maintain road traffic. In this case, however, planking is limited to a minimum and it is provided only downtown. It will be necessary, therefore, to restrict general traffic on the road except for the downtown area.

The concrete forms for the tunnel are to be of steel and the timbering is also to be of steel piping, which will enable repeated use of these materials to reduce the cost.

In principle, concrete is to be transported from a large scale mixing plant in mixers avoiding mixing at the individual work sites.

Because of favorable soil conditions, filling in over the tunnel is to be made with soil that has been excavated, as far as possible. For this purpose, however, it will be necessary to have smooth coordination in the progress between excavation and filling in.

The road is to be paved temporarily after filling in, and a permanent pavement is to be made after the roadbed has firmly settled.

Unlike the open-cut method, the shield tunneling method does not increase the construction costs sharply in proportion to the depth of excavation. Because of favorable soil conditions in this area and no possibility of spring water, the approximate cost per unit length may be determined for sections having more than a certain depth. Accordingly, the cost was estimated on the basis of the cost per unit length obtained from the record of actual work done by the shield tunneling method in similar soil conditions.

For the elevated structure, the cost was estimated on the assumption that reinforced concrete slab-beams type are used for the majority of the sections. In this case, the use of foundation piles is not considered because of the favorable soil structure.

Cost of buildings:

For the underground stations, the cost of interior finishings were also estimated and the cost of the station buildings were calculated by multiplying the finished floor area by the unit cost. The unit cost in this case was determined on the basis of completed work similar to this but the unit cost for the key stations downtown differs slightly from that of the stations in the suburban area.

For the elevated station, the cost of platform sheds and interior finishings in the stations below the elevated structure was calculated in a manner similar to the above.

Cost of tracks:

The cost was estimated on the assumption that a concrete roadbed will be used in the tunnel sections and a ballast roadbed will be used for the elevated structure. The tracks in the rolling stock sheds were assumed to be on a ballast roadbed with slightly simpler construction than that of the main line.

The cost of the electric circuit and auxiliary facilities includes the cost of buildings such as substations.

The cost of rolling stock sheds includes the cost of civil works, buildings and tracks.

As the cost of rolling stock was estimated on the basis of the quantity of rolling stock needed for operation intervals of 2-1/2 or 3 minutes, the technically feasible limit, the number of cars for the operation intervals of 5 minutes in the initial stage of operation may for the time being be 1/2 that of the minimum number of cars required.

Administrative costs:

The administrative costs are to be calculated by multiplying the above total costs by a certain percentage. The percentage was set at 6% in the light of past experience.

The above total represents the construction costs but it does not include the cost of land and interest during construction.

For the cost of the right of way in the case of a subway, the work under the road does not entail cost for acquisition but the work under privately owned land will entail costs either for the purchase of the land or for compensation for the underground portion. The elevated structure will also entail costs for the purchase of land. In any event, extra costs must be calculated under the prevailing conditions and added to the construction costs.

Interest during construction is the interest to be paid during the period from the procurement of the land to the inauguration of operations. As the interest rate varies depending on the method of procurement, no estimate of interest was made in this case. Interest rates under the prevailing conditions must be calculated and added to the construction costs.

Table 4-6-6 Itemized construction cost

(Unit: million reals)

Classification	Route No. 1 29.5 km	Route No. 2 23.2 km	Route No. 3 32.2 km	Route No. 4 37.1 km	Total 112.1 km
Cost of:					
Structural works	6,400	5,370	5,030	5,130	21,930
Buildings & interior finishings of stations	250	250	240	250	990
Tracks	230	270	370	420	1,290
Electrical equipment	1,290	1,340	2,030	1,620	6,280
Car sheds	550	350	870	560	2,330
Cars	1,540	1,470	2,450	2,250	7,710
Administration	620	540	660	610	2,430
Total	10,880	9,590	11,650	10,860	42,960

4.6.12 Management plan

(A) Procurement of funds

Procurement of funds is a serious problem which may decide the future of the enterprise. Various means of raising the required funds are being contemplated in many cities in other countries.

In San Francisco, for example, the construction costs(approximately $800 million) are financed by a fixed asset tax and by bonds redeemable in 37 years, and the remainder (approximately $130 million) are covered by a surplus from the toll charges at the Oakland Bay Bridge. In Toronto, about 70% (the cost of the right of way and construction of structures) of the total construction costs were financed by the city, and the remaining 30% (track and auxiliary facilities) was paid by the Toronto Transit Commission. However, because of the extreme burdens imposed in the construction of subways, the Federal and the State Governments are now granting subsidies for the construction. Subway construction in Tokyo and New York is also being supported by financial and from the Central Government.

In this way, efforts are being made in many cities to keep the fares at a low level by eliminating the effects of the construction costs. It will also be necessary for Teheran to make a full study of the means of procuring the funds required for the construction of subways.

(B) Operation

As a general guide to the management plan, calculation should be made on details of personnel costs, cost of supplies and power costs in Teheran. However, because of many uncertainties about the actual situation in Teheran, examples of the costs in Tokyo will have to be used (Table 4-6-7). This table does not include the depreciation value in the expenses and interest.

When the transport distance is great the fare should be determined according to the kilometerage rate. In the case of urban transport, however, the flat fare system is being adopted by many cities in the world. The adoption of a flat fare system requires a wicket only at the entrance and eliminates the need for collecting tickets from passengers getting off the train. Besides, the sale of tickets will become very simple and the use of simple vending machines also becomes possible. As a result, the operating expenses can be reduced considerably.

In Teheran the adoption of the flat fare system is considered justifiable until such time as the extension of the line is effected and long distance transportation has come into existence.

Table 4-6-7 Actual examples of operational costs (Tokyo Subways 1968)

Items of costs		Costs for 1968	Costs/ km
Train kilometers		92,771,700	1 km
Labor costs	unit; reals	13,331,722,510	14.35
Expenses for breakdowns		720,496,270	7.77
Track maintenance	"	98,000,760	1.05
Electric circuit maintenance	"	49,218,370	0.53
Car maintenance	"	144,855,740	1.56
Operating & transporting	"	126,039,880	1.36
Electric power for trains	"	196,782,820	2.12
Maintenance & administration		18,632,970	0.20
Transport management	"	6,559,310	0.070
Car line	"	68,418,260	0.738
Head office	"	11,988,160	0.129
Others (taxes, etc)	"	90,164,820	0.97
Total operational costs		2,142,384,100	23.09
K.W.H.		235,303,560	2.536
Total length of subways		92.8 km	

4.7 Monorail

4.7.1 Monorail Project

As stated previously, four different routes have been proposed to form a rapid transit railway network for Teheran city which is expected to have a population of 5.5 million in 1991 and preliminary specifications and estimated construction cost for subway system for the event this system is adopted, for each of the proposed routes have been presented.

However, in view of the necessity of minimizing construction cost with the consideration of future transport demand, topography of Teheran city having many steep slopes and the geology having a sufficient bearing power, and also in consideration of problems caused by noise, which may become the center of public attention when the present elevated railways constructed in the suburbs of the city will be running right in the city area which is expected to be formed along the railway lines and enbrace the railway from all directions, a monorail plan has been worked out for two specific routes which are considered most suitable to the characteristics of monorail system to compare with the subway plan. Outline of this project is given below.

Comparative study for Route 3 and 4, which run from east to west under the linear pattern city planning, is excluded from discussion at this stage and the planning of preliminary project and estimate of construction cost will be made only on Route 1 which originates in front of the Central Station of the State Railways, runs through old city center where Bazars are located and the present government district, traversing a new government district planned for Abass-Abad and reaches Tajrish and on Route 2 which connects the State Railways with a new station planned for Karaj in the west about 8 km from the Central Station, crosses Mehrabad Airport in the form of underground structure, runs above through Shahreza and reaches Teheran Pars. Reasons for selecting Route 1 and Route 2 for comparative studies are given below.

Route 1. This route runs through Teheran city from south to north and its maximum gradient is 50‰in some sections. Besides, in subway project, the entire route must be made of underground structure, which will inevitable increase construction cost.

Although the operation of train in the section with this gradient may be possible but this is almost the limit of ascending ability of train. The monorail, meanwhile, making the best use of its advantage, a greater adhesion coefficient, is able to secure maximum ascension power of 100‰ even under the worst weather condition. Therefore, the operation of monorail is possible at the section having a gradient exceeding 67‰with sufficient reserve power. Accordingly, if specific measures are taken to prevent adverse effect on the existing city area, the entire section of Route 1 may be built with elevated structure to save construction cost.

Route 2. This route enables construction of monorail line over the medial dividers provided in the Airport Road-Kh.Eizenhower - Kh. Shah Reza without blocking the present road traffic, thus saving construction cost considerably.

4.7.2 Type of Monorail

The monorail is a special railway which travels through vacant air space above the streets and its extension directly into conventional railways is not possible. Therefore, this system must have its own specially built track.

The monorail car straddles on its track beam or hangs down from the beam. The beam and pylon may be built much slender than those required for conventional elevated railways. This system, therefore, is suited to the route which runs over the roadway and waterways. Appearance of track structure is lightness and involves less sun-shine shielding problems compared with other elevated railways. Besides, the adoption of rubber tires as a means to prevent noise, the problem always associated with urban railways, minimizes possible injury to the environment as compared with conventional railways.

The monorail now in practical use has the following four types and a general view of each of them is shown in Fig. 4-7-1. The result of their operational performance is shown in Table 4-7-1.

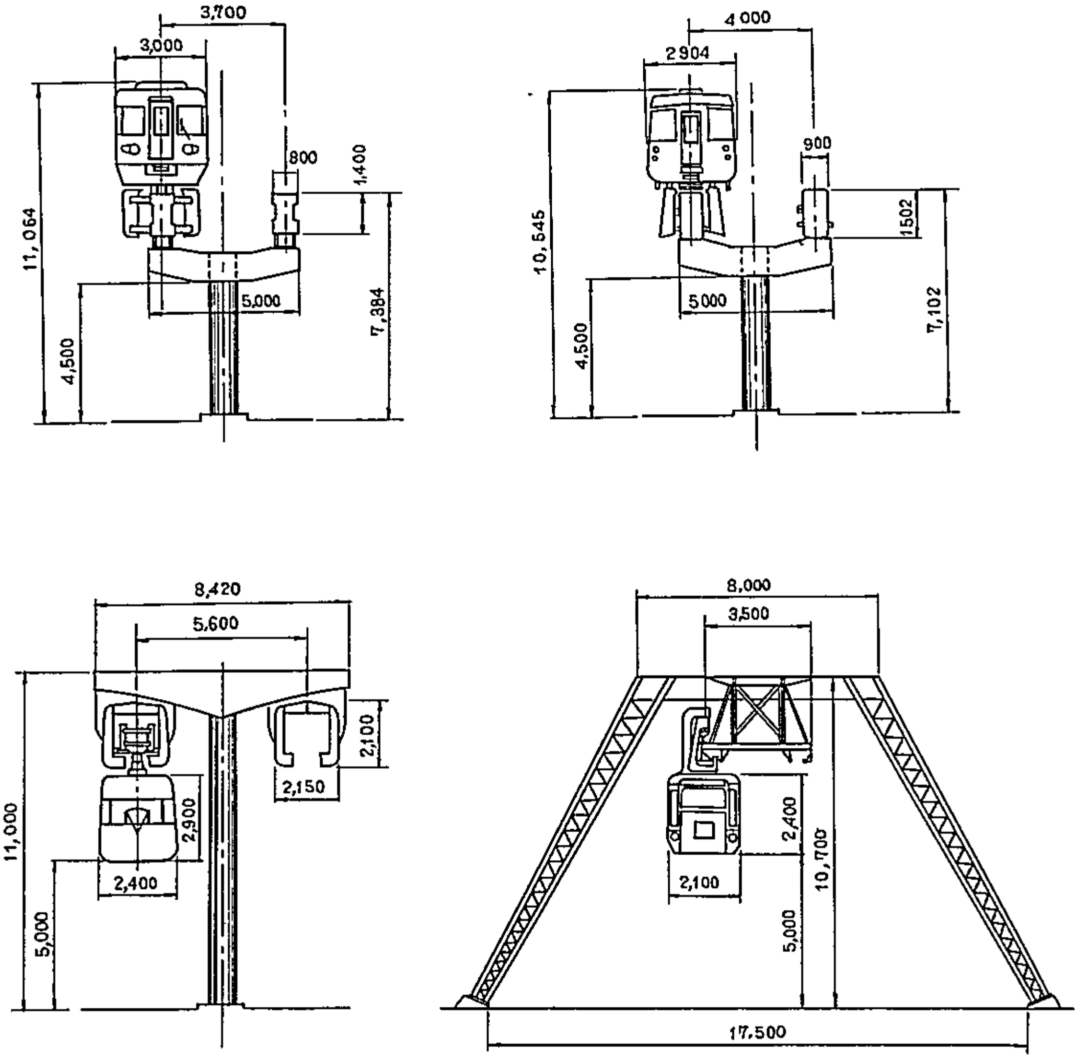


Fig. 4.7.1 Monorail system

Fig. 4-7-2 Haneda-monorail-line (Japan)

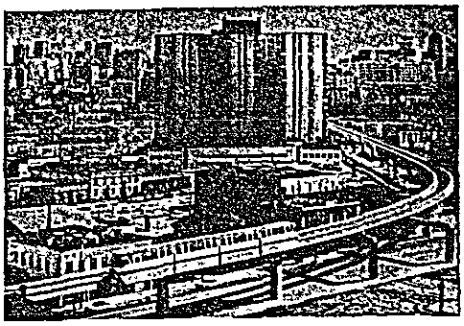


Fig. 4-7-3 Seattle-monorail-line

(1) Alweg system

In the standard section, the car straddle on the P.S. concrete track beam having a narrow I section, which is placed over the slender one-legged re-inforced concrete pylon, and travels with its vertical driving wheels that support vertical load of the car horizontal guiding wheels and horizontal stabilizing wheels. This is the so-called straddle type. For the section where the width of pylon is limited, or the height of pylon is greater or where span exceeds 20 m, steel pylon or steel track beam must be used. Owing to the use of highly efficient rubber types on wheels, it has succeeded in attaining noiseless running which is always the focus of public attention associated with urban transport, and affords a comfort-able operation. This system has the highest record of performance among various systems of monorail. The Haneda Monorail line spanning a distance of 13.1 kilo-meters (double track) between Tokyo International Airport and the center of the Tokyo is in practical use as a means of urban transport and is showing a good business result.

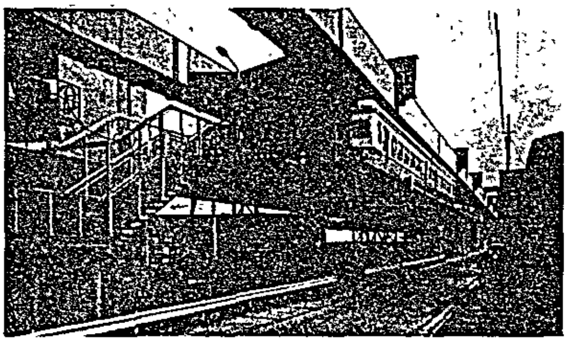


Fig. 4-7-4 Syonan-monorail (Japan)

Fig. 4-7-5 Higashiyama-monorail (Japan)

(2) Lockheed system

This is also a straddle type as in the case of Alweg System but its wheels, both vertical and horizontal, are steel and travel on three steel rails provided on the surface and both sides of P.S. concrete beam having a rectangular section. Because of steel track and steel wheels of the car, high speed operation (over 120 km/h) is possible with this type but it is more disadvantageous than Alweg system with respect to noise problem.

Table 4-7-1 Monorail system of the World

Type	Location	Year Completed	Purpose	Total length (km)	No. of racks
Straddle type (Alweg)	Fühlingen (West Germany)	1956	Experiental	1.8	Single
"	Disney land (U.S.A.)	1959	Amusement	1.34	"
"	"	1961	Transport of passengers	2.6	"
"	Torino (Italy)	1961	"	1.16	"
"	Seattle (U.S.A.)	1962	"	1.59	Double
Straddle type (Hitachi-Alweg)	Inuyama (Japan)	1962	"	1.39	Single
"	Yomiuri Land (Japan)	1963	"	1.97	"
"	"	1964	"	1.13	"
"	Haneda "	1964	"	13.1	Double
Straddle type (Toshiba)	Nara (Japan)	1961	Amusement	0.9	Single
"	Yokohama Dreamland (Japan)	1966	Transport of passengers	5.4	"
Straddle type (Nippon Lockheed)	Gifu (Japan)	1962	Experimental	0.86	Single
"	Mukogaoka (Japan)	1966	Transport of passengers	1.1	"
"	Himeji "	1966	"	1.63	"
Straddle type (Hitachi-Alweg)	Osaka Expo'70 (Japan)	1970	Transport of passengers	4.3	Single
Suspension type	Wuppertal (West Germany)	1901	Transport of passengers	13.1	Double
"	Tokyo Ueno (Japan)	1957	Amusement	0.33	Single
Suspension type (Safege)	Suburbs of Orléans (France)	1960	Experimental	1.4	Single
"	Higashiyama Park (Japan)	1964	Transport of passengers	0.47	"
"	Shonan "	1970	"	4.6	"

(3) Safege system

This is a suspension type which the car hungs down from the bottom of truck which travels inside the box-type steel beam with open bottom and supported by steel pylon. The truck has vertical wheels that support the load and horizontal wheels that guide the movement of the truck. Both vertical and horizontal wheels use of highly efficient rubber tyres. This system is compatible with the Alweg system with respect to noise and conform in riding and is advantageous in that the platform may be provided at low level. However, this system inevitably increases the height of pylon and requires larger section of beam and therefore is disadvantageous with respect to harmony with surrounding area in the city. Besides, the large box section beam is of complicated structure and must be made of steel, which, coupled with the increased height of pylon, requires more construction cost.

(4) Hook-Type Suspension System

The car hangs down from hook-shaped suspension arm which extends from the truck that travels with its steel driving wheels having a double flange on the steel rail provided over a narrow steel beam supported by steel pylon. Because of its huge steel beam and excessive noise produced by steel rail and steel wheels, adoption of this system as urban transport is very questionable even though it has an old history. This system now in existence in Wuppertal, West Germany, was constructed over the canal and has been in operation since 1901 without a single accident.

When the direct connection to other conventional railways is not required, the monorail system is very advantageous as urban transport in that it presents less possibility of damaging environments with respect to scenery, sunshine shielding and noise compared with elevated railways and that it requires a less amount of capital investment for construction compared with subways.

The primary reason of limited use of monorail as far in spite of its advantage in utilizing vacant air space of the city is that this system has a very few achievements as a means of mass transport in the past. The majority of monorail systems of the past, except the one in Wuppertal, West Germany, which has a long history, have very short operating distances and are used mainly for amusemental purpose. The only example of monorail used as full-fledged urban transport is the one now in operation in Tokyo with a total length of 13.1 km. Excellent result of Tokyo Monorail coping with a rapidly increasing traffic demand in recent years is worthy of special attention.

Secondly, the monorail system can demonstrate its abilities mainly through utilization of the space over the existing road and waterways but most old cities lack roads and waterways suitable for the construction of monorail. This may also be siad true with conventional elevated railways.

In the past authorization on the use of space over the roadway for railway was not easily given in Japan and the construction of elevated railways in the city area had entailed the acquisition of land for exclusive use in the crowded city area. Thus, mainly due to the restriction on the acquisition of land, advantages of monorail could not be fully utilized so far. Since then, the monorail has come to be studied not only as a means of transport of early days but as a means of urban transport compatible with the present and future city structure as part of a comprehensive study, and many technical improvements have since been made on the system. Also, while the need for mass transport facilities, which are able to satisfy ever increasing demand for urban transport, is being stressed, skyrocketing of construction cost and longer construction period of subway are posing a serious problem. Against this, the monorail with its low construction cost, shorter construction period, light construction of elevated structure and less noise problem has come to be given special attentions and a detailed plan is being worked out for authorizing the use of space over the roadway for monorail construction. When a comparison is made between the monorail and subway the latter has an overwhelming advantage over the former in the section where emphasis is placed on the appearance of track and station facilities or the obstruction of surface space but the monorail is more advantageous because of its low construction cost and shorter construction period in the area where there is no requirement for direct extension of service into the existing railways and where the use of space over the roadway or waterway is permissible.

Although the monorail is a special independent railway and requires elevated bridges supported by a single slender pylon, it may be built underground without difficulty for the section where elevated structure is not practical such as busy streets in downtown area, airport or hilly districts with rugged terrain.

4-7-3 Plan and Profile Planning

Plan and profile planning are shown in Fig. 4-7-6, 4-7-7 and 4-7-8.

(1) Route 1

This route originates in front of the Central Station of State Railway, runs through Kh. Shoosh Kh. Arim gah Kh. Kyayyah Kh. Sepah Kh. Saadi Kh. Roozvelt, heads for north, runs through a proposed new government district planned for Abbas-Abad and reaches Tajrish, with a total length of 19 km. Extension of service to Evin in the future must also be taken into consideration. As this route runs through existing old city area, there is no much room in the width of road and some difficulties may be encountered in selecting the site for building a station. However, the expense required for the solution of problems of local nature is considered far less than that required for constructing underground structures and therefore the entire section should be of elevated structure. Even at the section where city street makes irregular turns, the car having a minimum allowable radius curve of 30 m can travel without difficulty and therefore the obstruction to the existing building can be minimized.

Longitudinal slope at every stations was held at 10‰ (allowable 25‰) in consideration of safety at the time of stoppage of the train and the easiness in starting the train. The maximum gradient of 67% is within the range of ascention without difficulty.

(2) Route 2

This route originates in the center of Teheran Pars at the point where the junction to Route 4, runs along Kh. Shah Reza Kh. Eizenhower Kh. Soos which crosses the center of Teheran city from east to west, comes to Airport Road, crosses Mehrabad Airport in the form of underground structure and reaches the junction to the State Railway, with a total length of 23 km. Consideration must be given to the future extension of the route on both ends when need arises.

This Route 2 runs relatively flat terrains and involves no specific problems with respect to the design except it crosses over super expressway at

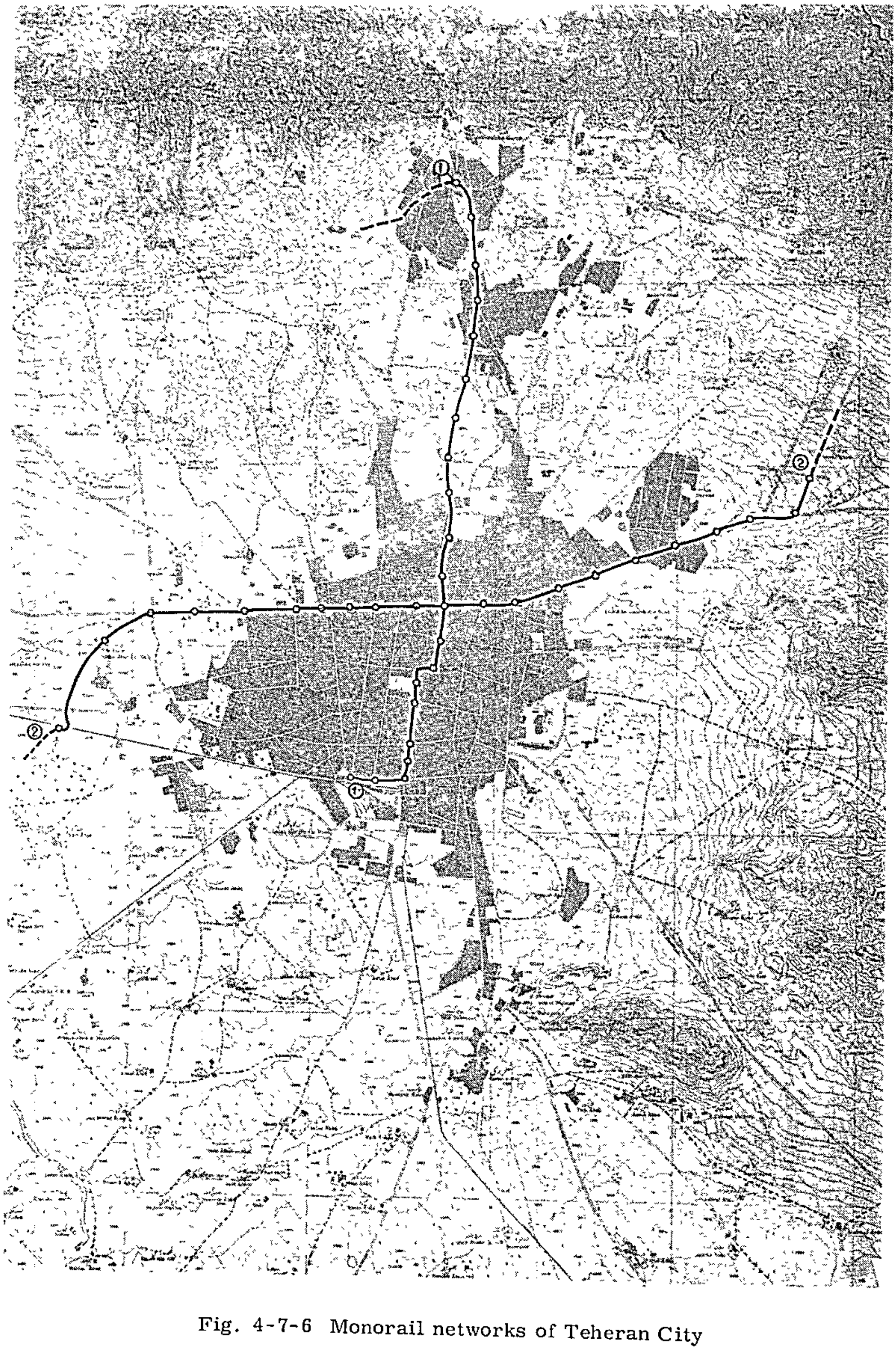
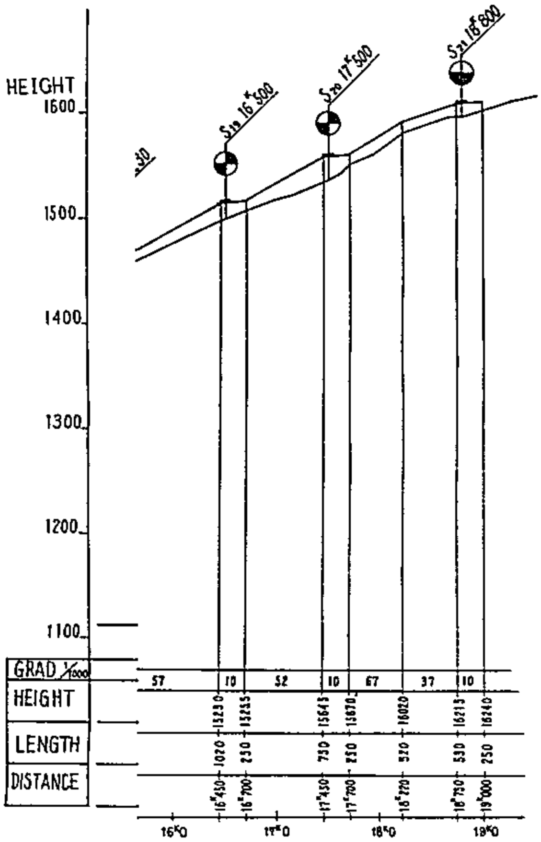


Fig. 4-7-6 Monorail networks of Teheran City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1600
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LENGTH
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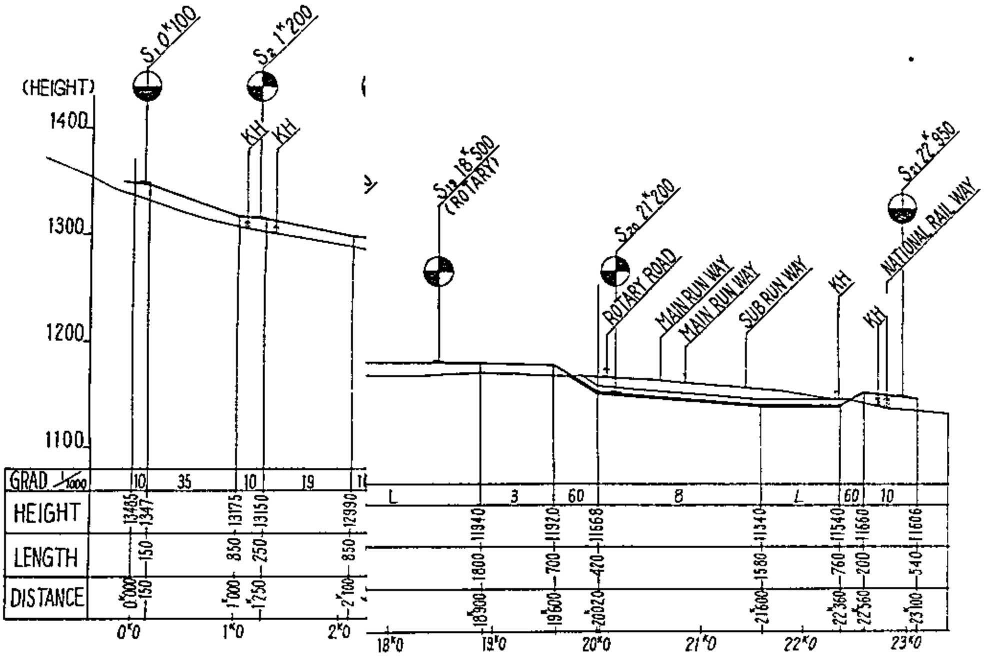
(HEIGHT)
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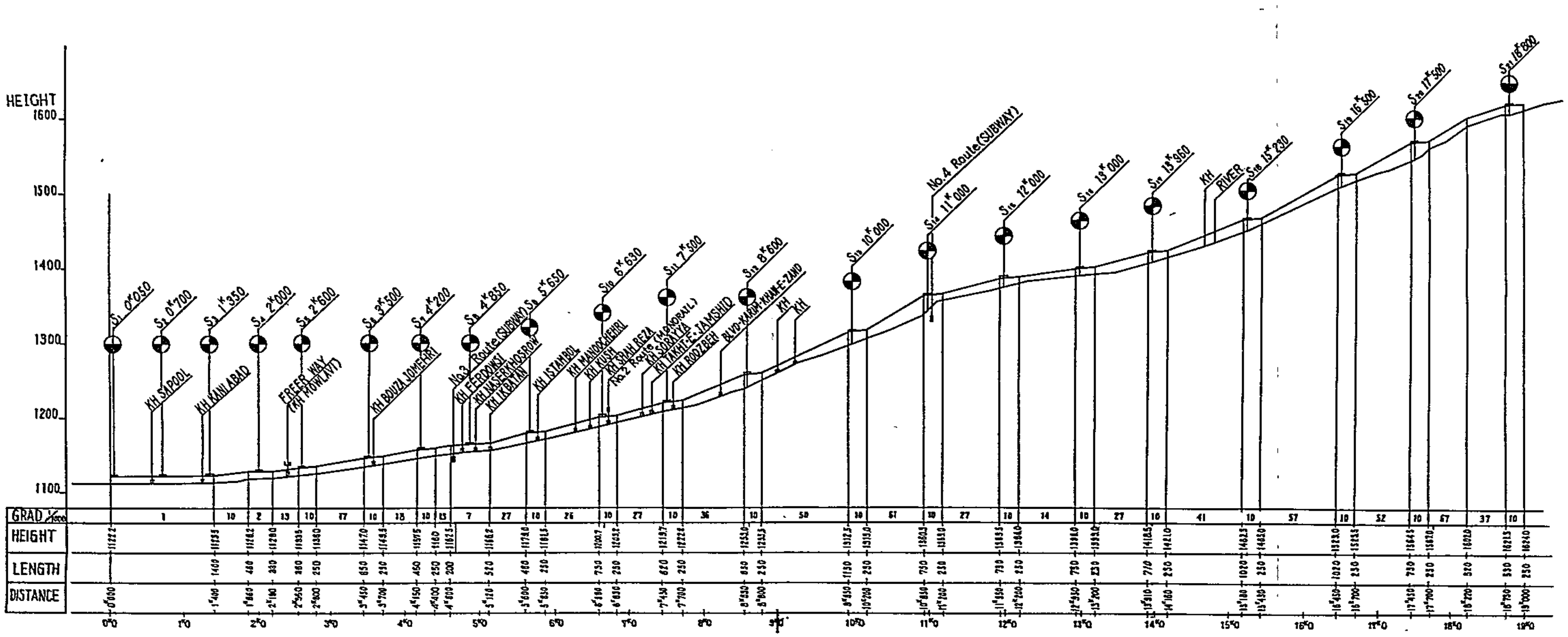


Fig. 4-7-7 Profile of route No. 1 (Monorail)

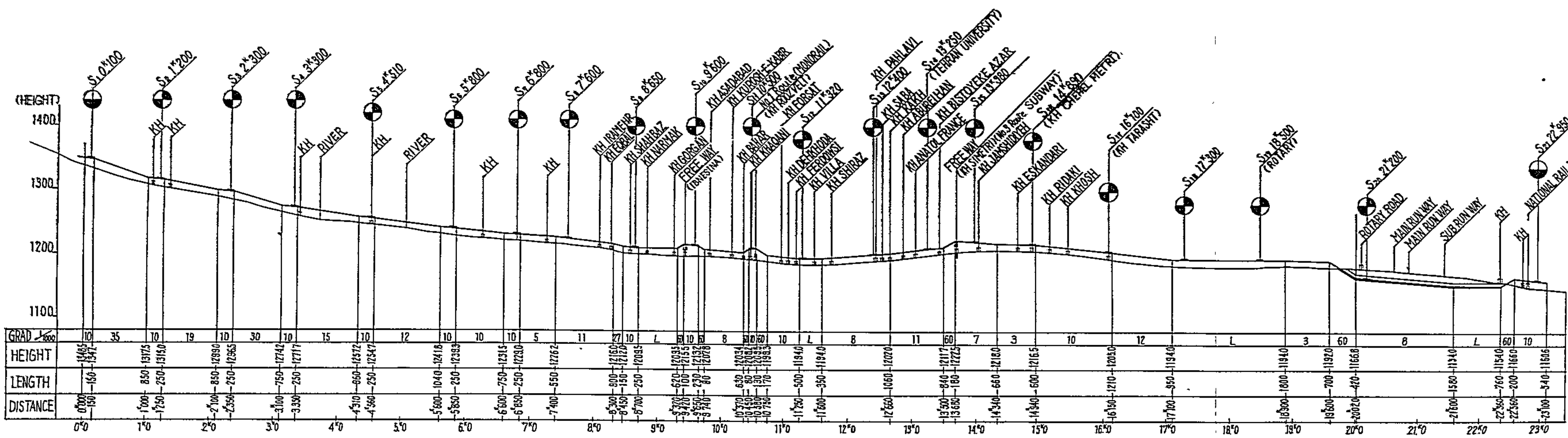


Fig. 4-7-8 Profile of route No. 2 (Monorail)

two points and the monorail track of Route 1 at one point, runs through the underground of the airport by shield tunnel and crosses over the State Railway. However, consideration must be given to the arrangement of track, particularly the station building, to maintain harmony between the structure and the surrounding city area.

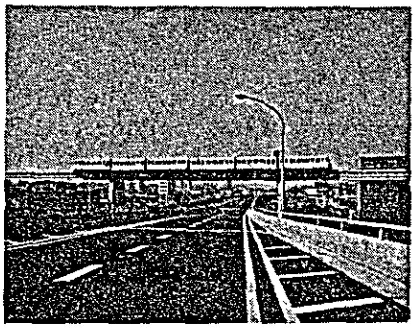
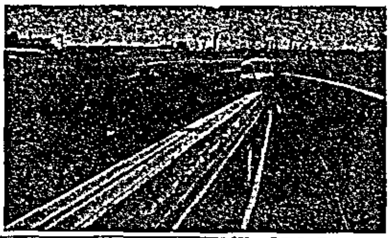


Fig. 4-7-9 Passing over the elevated freeway (Haneda-monorail, Japan)



From the entrance shown in the photograph, the line enters into the tunnel, turns to the left and passes underneath Runway B of Haneda Airport. Because the tunnel was constructed while the runway above was being used, the shield method was utilized The grade at this entrance is the steepest point (60/1,000) on the entire Haneda Monorail Line.

Fig. 4-7-10 Entrance to the tunnel at Haneda

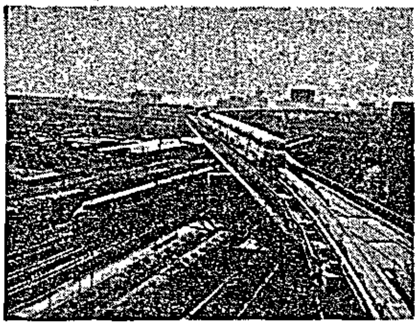


Fig. 4-7-11 Crossing the national railway tracks (Haneda-monorail, Japan)

4-7-4 Location plan of stations

As a means of urban transport, stations on both routes should be located close to the intersections of road and at intervals of about 1 km depending on the congestion of the city area. Spacing of stations at greater intervals in an attempt to increase the speed of train and to save construction cost will only result in the difficulty in attracting passengers and failure to play the role of urban transport, thus failing to alleviate the congestion of surface traffic.

As shown in the plan and profile of the two routes proposed for Teheran, Route 1 will have 21 stations with an average distance between stations being about 950 m and Route 2 will have 21 stations with an average distance between stations being about 1 km 100 m.

4-7-5 Standards and Specifications

(1) Type

Alweg system monorail is to be adopted. Outline of this type has already been given in 4-7-2 (1).

(2) Electric system

Direct current is to be used as the motive power of cars. The voltage is to be 1, 500 V and the supply of power is to be made by power supplying rail provided at the side of track beam through collectorshoe of the car details of which will be discussed later.

1, 500 V power has already been proved effective for monorail in Japan and is particularly suited to monorail which has a limit in size and number of power supplying rail.

(3) Rolling stock gauge, construction gauge and tunnel gauge

Rolling stock gauge and construction gauge are to be as shown in Fig. 4-7-12. The car rides over the beam and travels with its vertical wheels

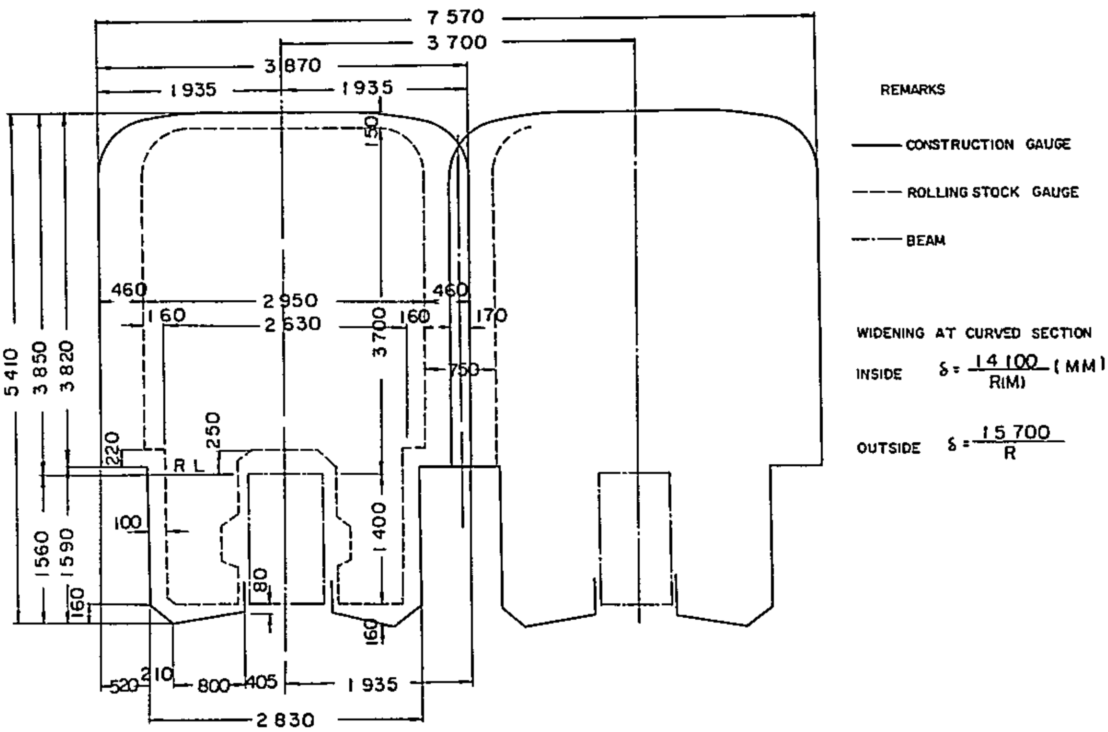


Fig. 4-7-12 Construction gauge and rolling stock gauge

so arranged to make a contact with the surface of track beam, as if to enbrace the beam with its horizontal wheels. To prevent the car from coming into contact with structure even when the car tilts 8 degrees to the vertical line at the center of track beam, the clearance on the side of both gauges is to be 460 mm. At the center of the side of track beam, where power supplying rail is to be provided, the rolling stock gauge is depressed.

The gauge is to be widened at the curve portion by the following formula.

$$Lm = \frac{14,100}{R} \text{ (mm)}$$

$$Lm = \frac{15,700}{R} \text{ (mm)}$$

where: R; Radius of curve (m)
Lm; Widening limit at outside of curve (mm)
Le; Widening limit at inside of curve (mm)

Tunnel gauge

Tunnel gauge is shown in Fig. 4-7-13.

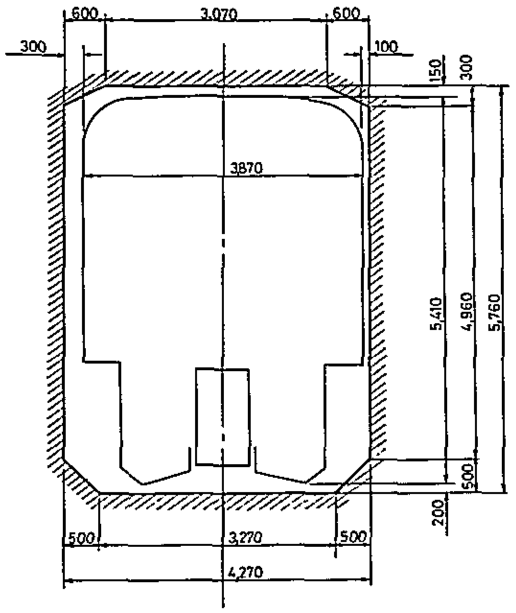


Fig. 4-7-13 Gauge for tunnel

In the case of monorail, maintenance work on the track during operating hour is almost impossible even in the tunnel section and therefore the space for the shelter for track maintenance crew as in the case of subway is not required. Accordingly, the overhead space dimension of the tunnel is required only for the accommodation of power, signal and communication cables and lighting equipment.

Center distance is to be 3.7 m as shown in Fig. 4-7-12. This dimension is determined only by the requirement to avoid the contact with disabled cars on the other track and a clearance of 460 mm is to be maintained between the beam and construction gauge. For the center distance, the possibility of cars passing each other on double track tilt at 8 degrees simultaneously is very remote and therefore the standard is to be set for the event that both cars running in the opposite direction tilt at 6 degrees simultaneously.

(4) Live load

Live load is to be the train load of axle load shown in Fig. 4-7-14.

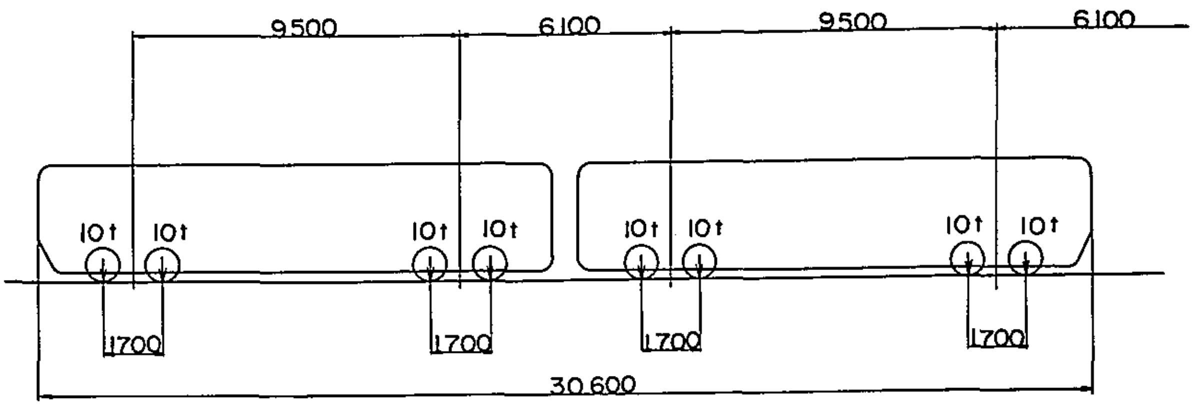


Fig. 4-7-14 Axle road (10ton/axle x 8 axles = 80 ton)

(5) Curve and gradient

Minimum radius of curve

At the advantage at Alweg monorail is gained only when the track is constructed in the vacant air space over the roadway in principle, the route is often required to make a turn at a right angle at the intersection of road.

Accordingly, the minimum raidus of curve smaller than that for the conventional railway will have to be provided. In anticipation of extreme cases in which the roads having a width of 25 m cross each other at a right angle, the minimum radius of curve must be set at 30 m.

Transition curve

Transition curve is to be the same as that for the subway.

Cant and speed limit

With the Alweg monorail the car rides over the track beam and therefore the value of cant at curved section may be considered only with respect to the comfort in riding and no consideration is required for the pssibility of turn-over of the car.

For the curved section with the exception of switching section, the cant calculated by the following expression is to be provided.

$$Q = \tan \theta = \frac{V^2}{127.R} - 0.05 \leq 0.15$$

Where: Q ; cant (θ = Angle of inclination)

R ; radius of curve (m)

V ; maximum speed (km/h)

The above formula shows that the maximum value of established cant is set at

0.15 and the allowable value of centrifugal acceleration is set at 0.05 m/sec^2 $\doteqdot$ 0.051 g. By this formula it is known that if the maximum value of cant at the radius of curve of 200 m is set at 0.15, the average speed is 62 km/h but the operating speed may be increased up to about 71 km/h.

Calculated cant should be established with the center of track beam as the axis of rotation.

Ruling gradient

Since the Alweg monorail operates on the combination of rubber tire and concrete track beam a greater coefficient of adhesion may be obtained. Therefore, the ruling gradient is to be 100‰ (= 100/1000). At the station the ruling gradient is to be 25‰ (= 25/1000).

Vertical curve

Then the variation of track gradient is greater than 5% , a vertical curve is to be provided and its radius of curve is to be 500 m at the minimum and 700 m in general.

(6) Track

Load

Though it is natural that consideration must be given to the dead load, live load, impact load, centrifugal load, lateral load, wind load, traction load and braking load, the monorail track which consists of mainly the elevated structure must take intoconsideration the following seismic coefficient as seismic load.

Horizontal seismic coefficent	0.2 g
Vertical seismic coefficient	0.1 g

Pylon

Standard type of track is to be as shown in Fig. 4-7-15, 4-7-16 and 4-7-17. The pylon is to be of reinforced concrete as a rule and steel pylon is to be used only in special cases. These pylons are designed so as to make its area of occupancy smaller as much as possible to minimize interference with the existing road traffic. An example of pylons with the conceivable longest span is shown in Fig. 4-7-19. When the erection of pylon in the center of roadway is not possible for crossing the road or the road is extremely narrow, a steel rigid frame pylon is to be used for crossing over the roadway so as to prevent interference with vehicular traffice, as shown in Fig. 4-7-18. The height of the pylon is to be 4.5 m at the minimum from the ground surface to the lower edge of T-shape pylon so as to provide sufficient clearance for road traffic.

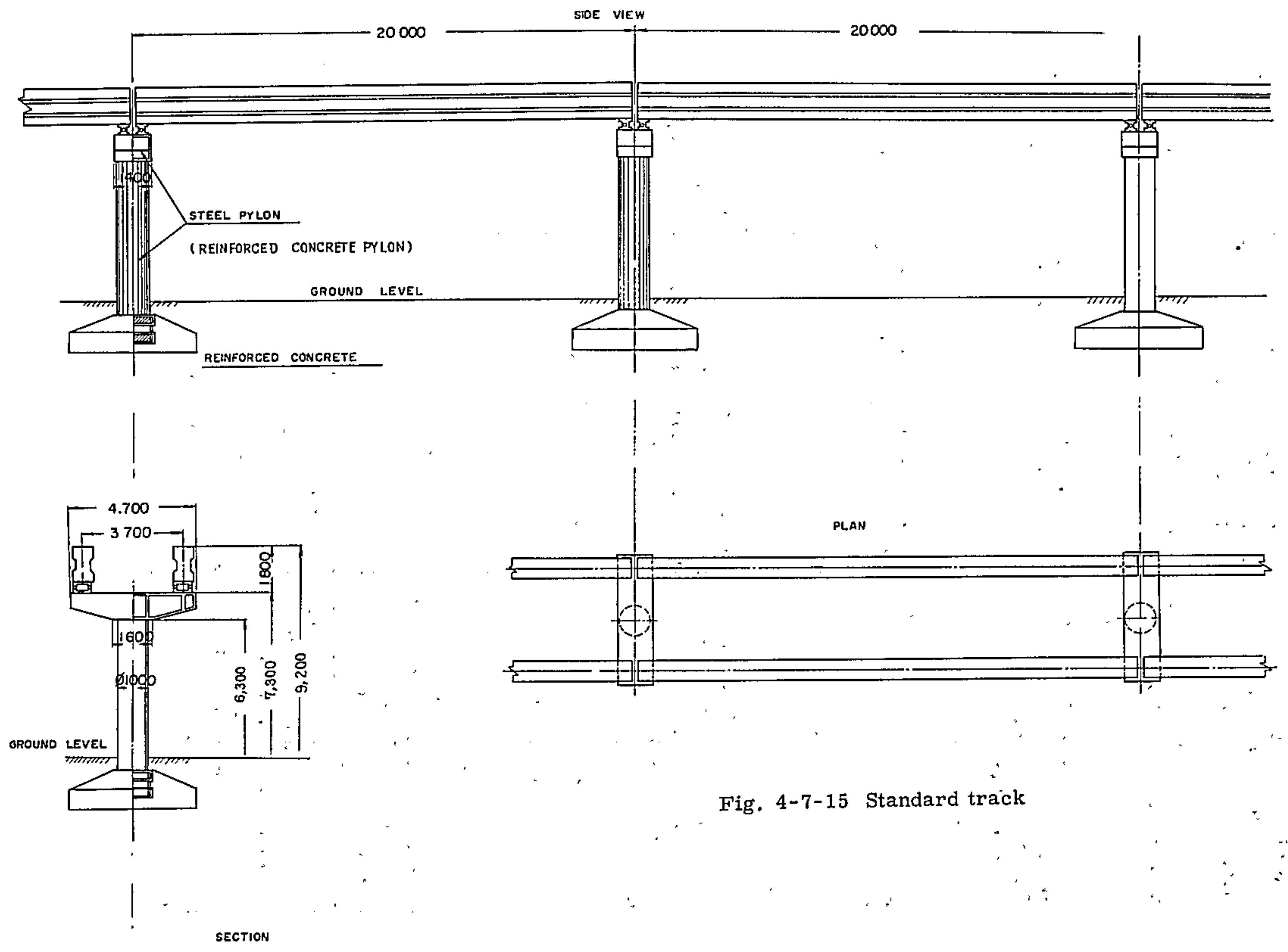


Fig. 4-7-15 Standard track

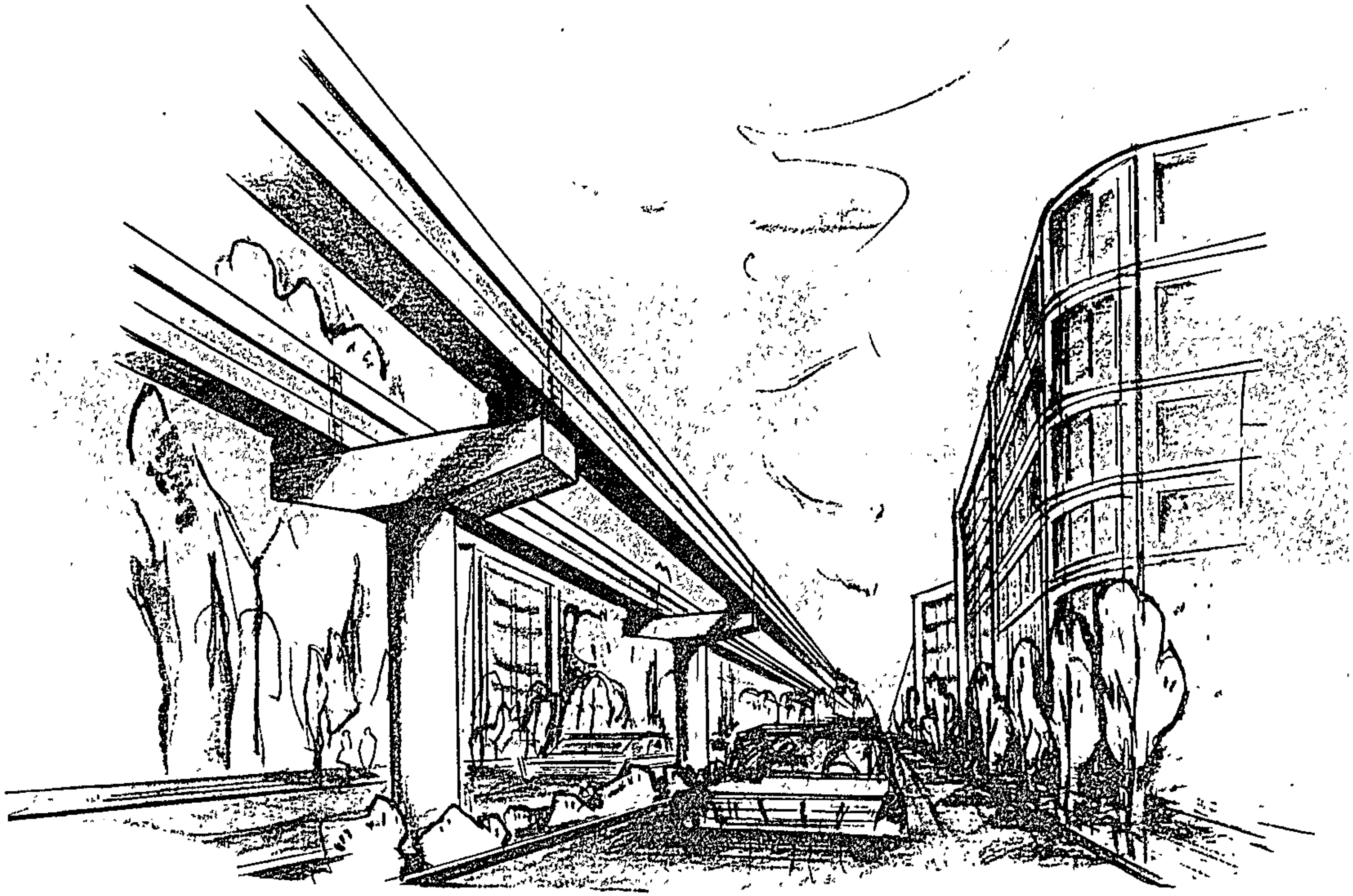


Fig. 4-7-16 Perspective drawing of T-type pylon

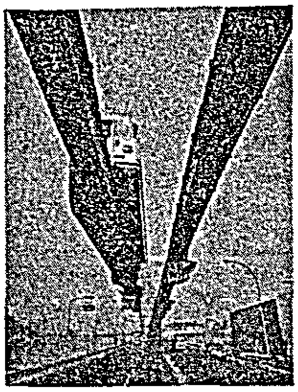


Fig. 4-7-17 Standard type of track

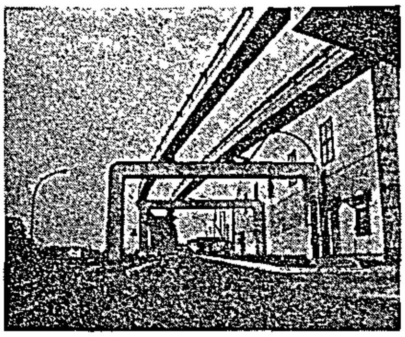


Fig. 4-7-18 Steal rahmen

Fig. 4-7-19 Finger-plate-electric power supplying rail shoe

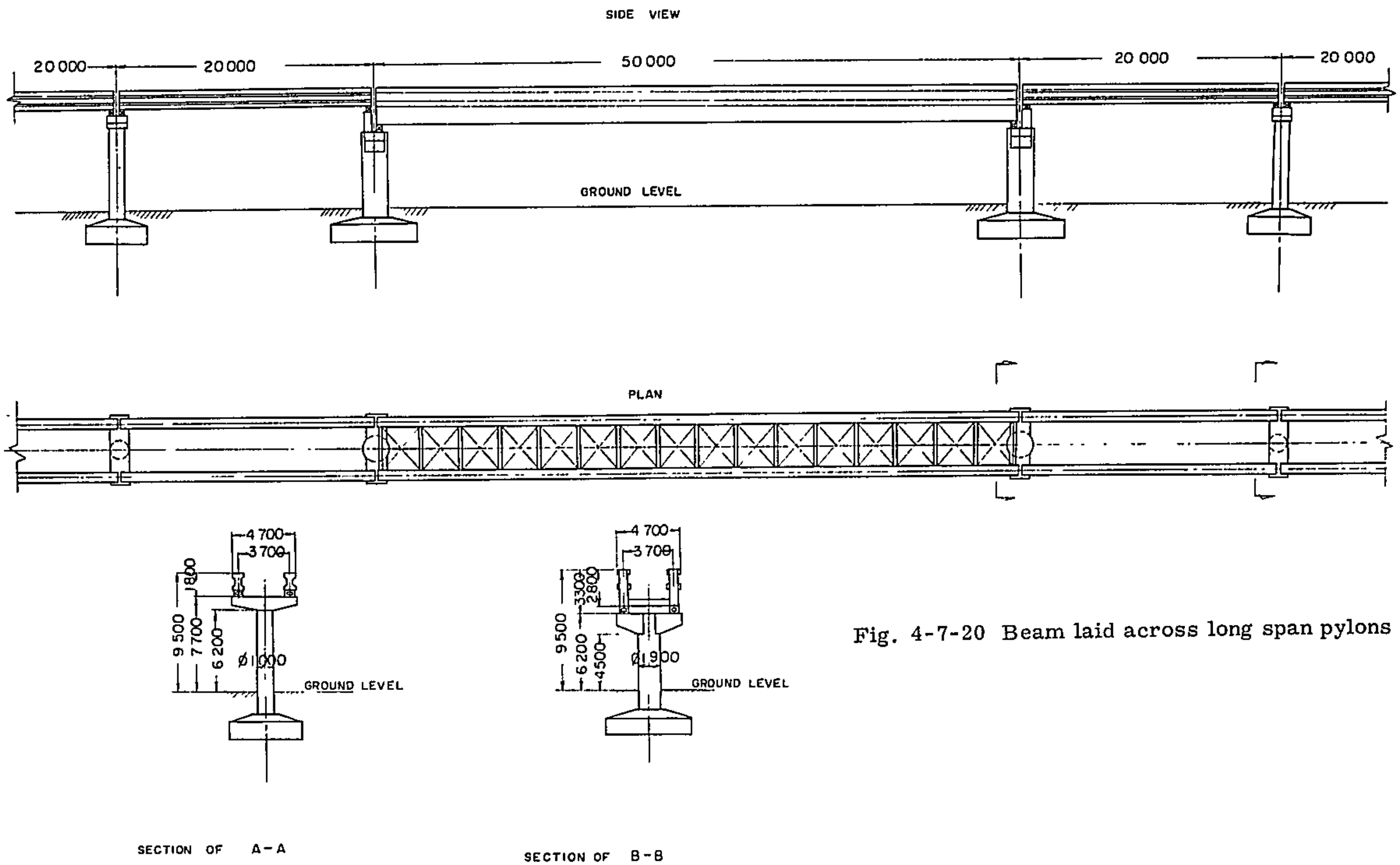


Fig. 4-7-20 Beam laid across long span pylons

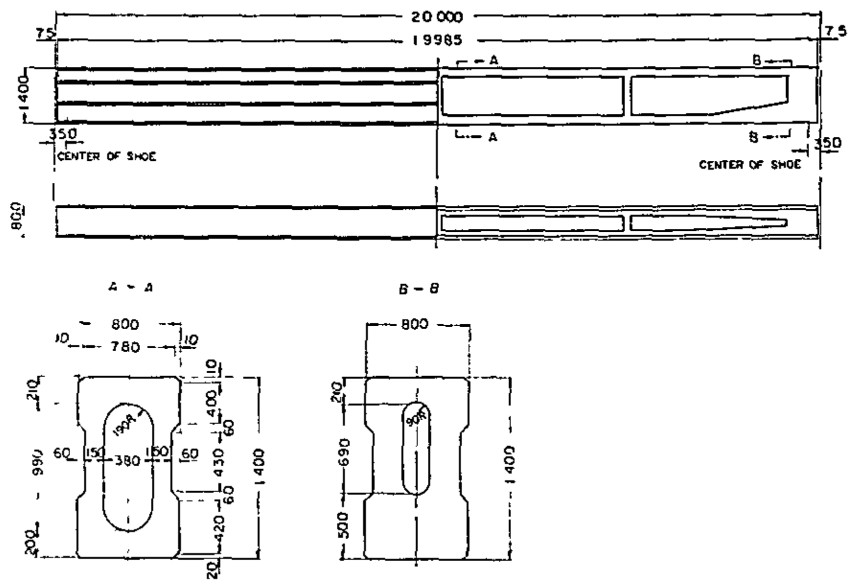


Fig. 4-7-21 Standard prestressed concrete beam

As mentioned in the paragraph for the subway project, soils in Teheran city comprise conglomerate mixed with boulders and therefore pile driving is not practical. However, since the bearing power of soil is considered to be sufficient in the area, the type of foundations for various structures is to be of mat foundation and allowable bearing power of soil is to be 50 t/m^2.

The surface of foundation in elevated section is to be at least 1.5 m in depth to protect underground facilities and the surface of tunnel in underground section is to be at least 2.50 m in consideration of sewage lines buried underground.

Track beam

Track beam is to be of prestressed concrete for the span less than 20 m in length. Its standard section is to be 800 mm in width and 1,400 mm in height and the inside is to be hollow, as shown in Fig. 4-7-22. The center of its side is to be depressed as shown in figure. Depressed portion at the center of the side is provided for the installation of power supplying rail.

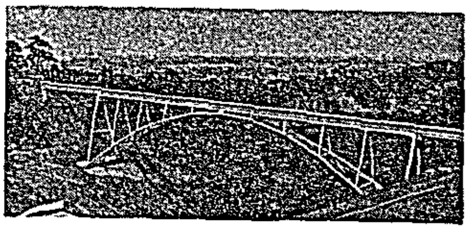


Fig. 4-7-22 Girder bridge (Yomiuri-Monorail, Japan)

Finger plate is to be provided at the joint of track beams as shown in Fig. 4-7-19 to ensure smooth running of the car over the joint of beams.

When the span exceeds 20 m, steel track beam is to be employed. Fig. 4-7-20 shows an example of steel track beams.

When an extremely longer span is required a specially built bridge consisting of mainly track beams is to be provided. Fig. 4-7-22 shows an example of specially built bridge.

Even when the steel track beam is used, the width of beam may be 800 mm, the same width as for the prestressed concrete beam, to obtain smooth operation of car but the height of beam must vary depending on the length of span.

Joint of pylon and track beam is to be made by shoe as shown in Fig. 4-7-23 and Fig. 4-7-19. The type of shoes available are the lower shoe which is

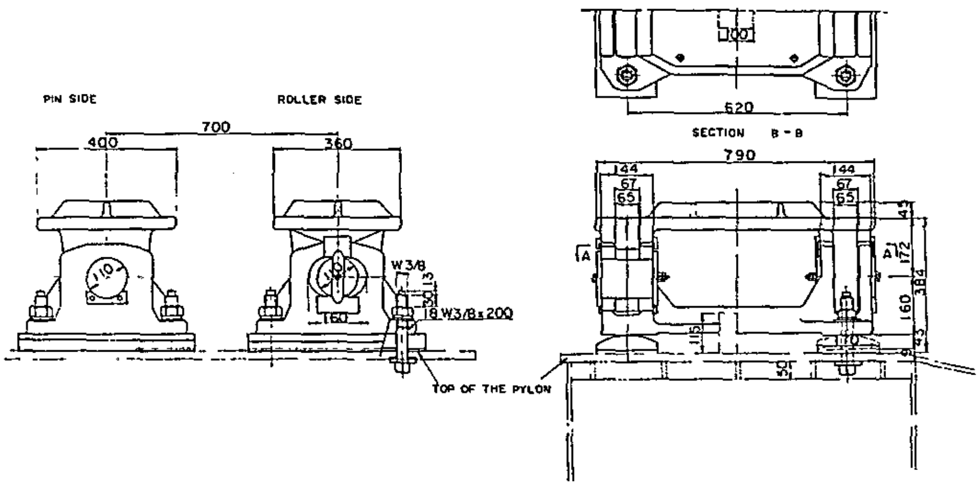


Fig. 4-7-23 Shoe

attached to the top of pylon and the upper shoe which is provided at the side of track beam. Joint of uper shoe and lower shoe is to made with a pin or roller. The lower shoe is fixed to the abovementioned pylon and tightened rigidly with anchor bolts. The anchor bolt is provided as a precautionary measure against the overturn of track beam which is caused by various horizontal loads applied to track beam.

Construction method

Construction work in the city area where traffic is heavy during daytime is to be carried out only at night in principle and careful attention must be paid to the road traffic even during the construction work.

Excavation and reinforced concrete working for the foundations of pylons are to be made at night only and to be covered with steel sheets during daytime to avoid interference with vehicular traffic.

Steel pylons are to be fabricated at the shop, transported to the site

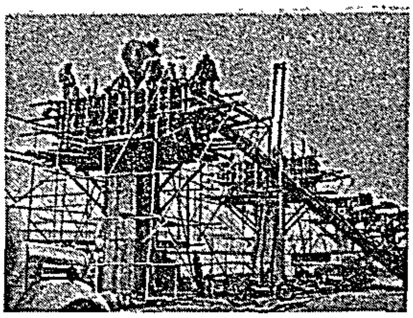


Fig. 4-7-24 Construction of pylons

at night by trailer and then erected by a truck crane. After making a full adjustment of span, alignment and height, steel pylon is anchored to the concrete foundation.

Reinforced concrete pylon is to be constructed at the site by providing moulding as shown in Fig. 4-7-24.

As the beam of monorail itself has a function of the track of conventional railways and requires highly precise workmanship, a special beam fabrication yard should be provided.

Facilities at the beam fabrication yard are shown in Fig. 4-7-25 through 28.

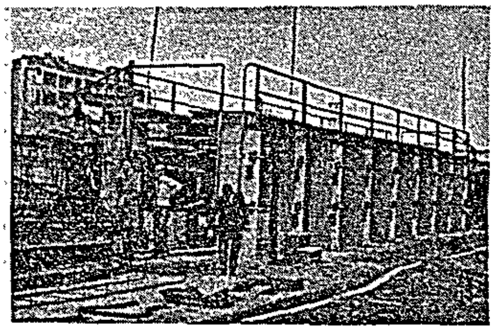


Fig. 4-7-25 Track beam factory, mold apparatus

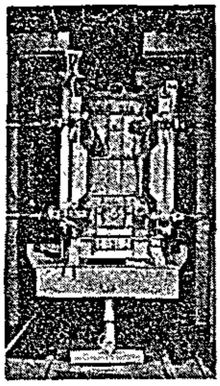


Fig. 4-7-26 Mold far fabrication of track beams

Fig. 4-7-27 Charging work of concrete beams

Fig. 4-7-28 Track beams in stock yard

For the erection of track beam in the street where traffic is heavy during daytime, the beam is to be transported to the site by trailer and placed on the pylon at night by two truck cranes.

After the beam has been placed, a final adjustment is to be made on the alignment, level and height of beam, and is anchored to the pylon.

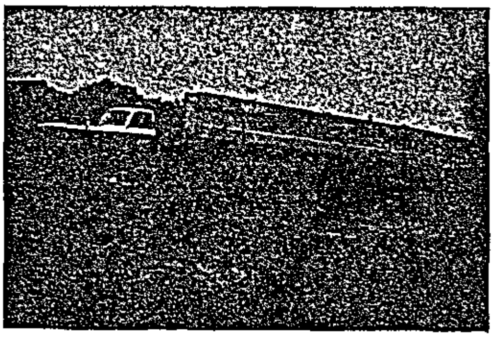


Fig. 4-7-29 Beam conveyed by trailer-truck

Fig. 4-7-30 Installation work of the track beam

(7) Switch

Switch is classified into the articulated switch and semi-flexible switch. Besides, there is the sciessors crossing which is a combination of several switches. The articulated switch is for low speed car and is made of two or more straight or curved beams joined together in the form of articulation and is used as a switch by bending it to the desired angle. In the case of the semi-flexible switch, the side plate of track beam, which makes a close contact with guide wheels and stabllizing wheels, is flexible to provide a smooth curve so that the car may travel at a high speed even on the switch. Fig. 4-7-31 shows the structure of an articulated switch and semi-flexible switch. Fig. 4-7-32 shows a general view of switch.

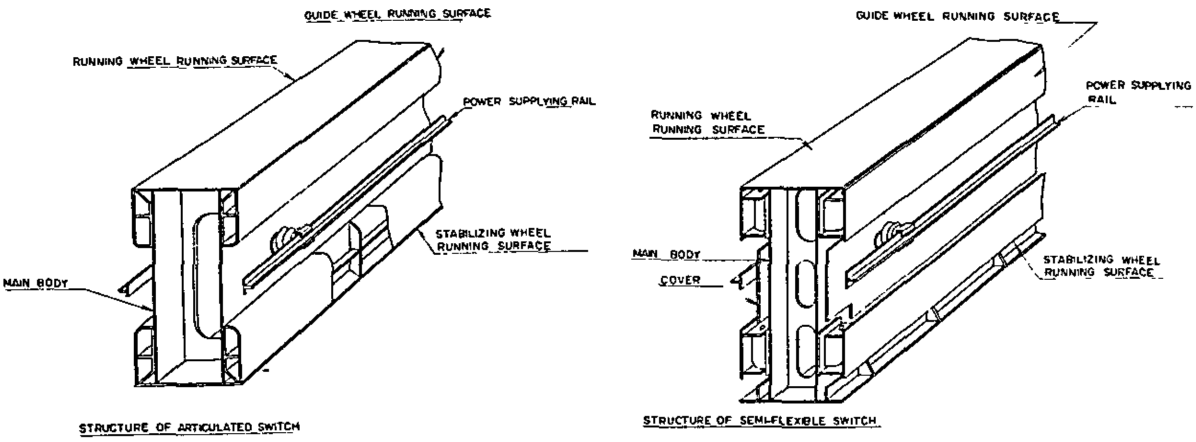


Fig. 4-7-31 Structure of switch

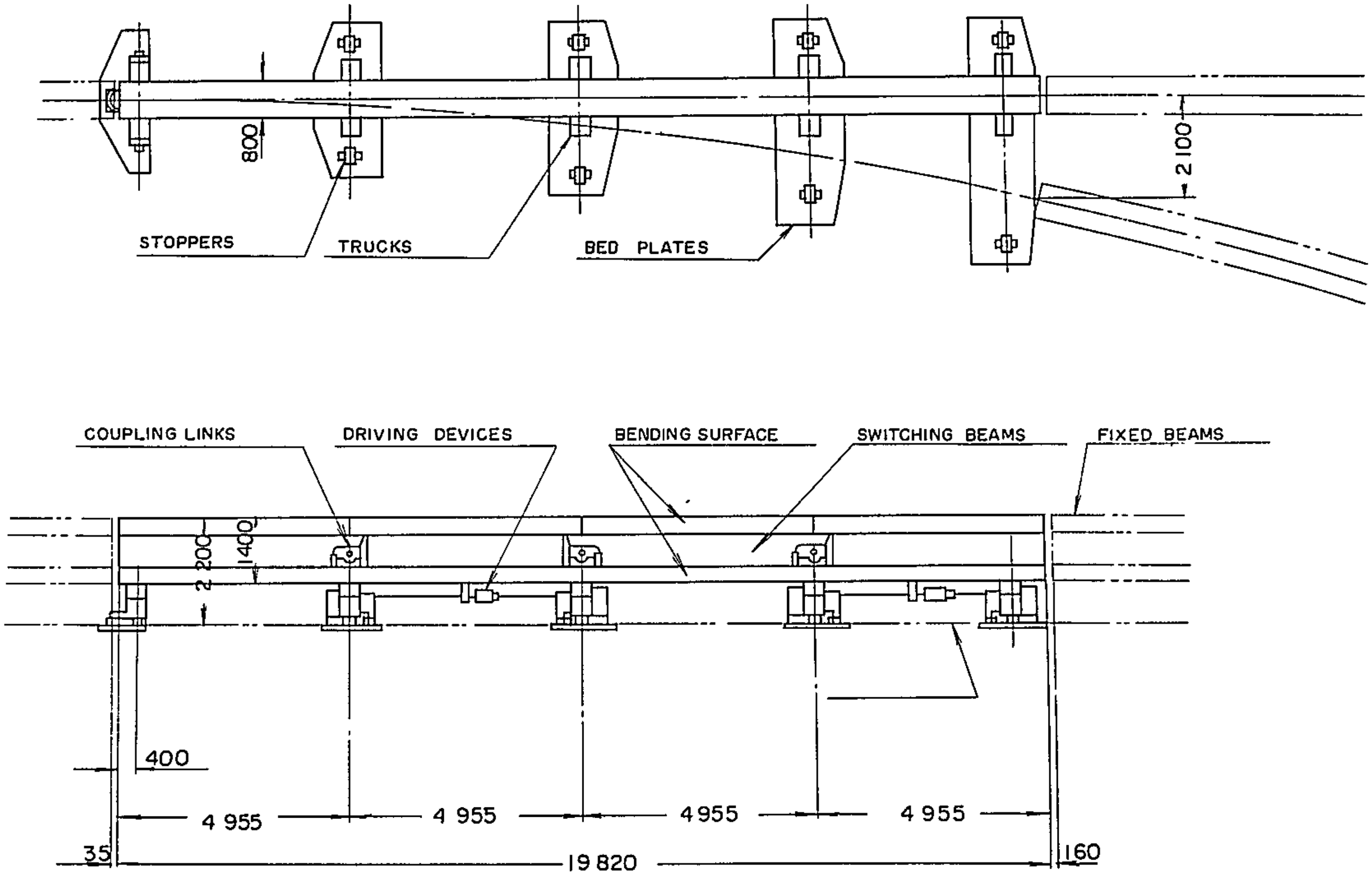
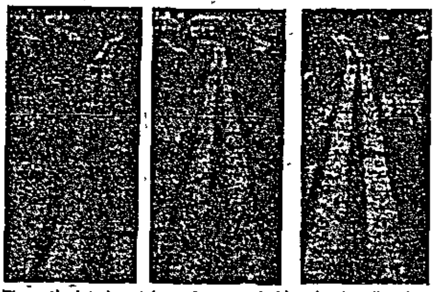
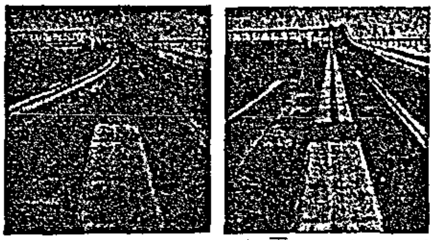


Fig. 4-7-32 General view of single-track switch



The articulated switch performs switching by bending two or more beams. Several trucks on which the beams ride are driven by a geared motor for each beam end for switching The photograph shows a three way switch in the car shed

Fig. 4-7-33 Articulated switch



A flexible beam is supported on five trucks, its movable end driven by a geared motor. Switching is made to straight and curved lines as shown in the photograph.

Fig. 4-7-34 Flexible switch

o Articulated switch

The articulated switch is a box structure of steel plate and is equipped with coupling links between it and the adjoining beam to prevent the movement of beam fore and off but to provide free movement from side.

Switching beam is supported by switching truck and the truck, which is fixed at the end of the switch, is equipped with a center pin, and sliding shoes are provided between the truck and bed plate so that the switch will move only in the direction of turn. As the movement of other trucks becomes a linear motion, trucks must be equipped with wheels.

Switching is made by electric motor and setting of switch position is controlled by limit switch and stoppers.

After switching has been made, the switch is completely locked in its position by locking device. Switching is to be made within 8 seconds.

To ensure safe operation of switch, electric control devices are to be provided, which control driving device and locking device electrically and confirm the completion of all required operations.

o Semi-flexible switch

Its structure is basically the same as the articulated switch, but it has flexible steel plates installed as horizontal running surface at the side of beam to provide a smooth curve for horizontal running and to eliminate obstacles to high speed operation of car.

This running surface, after switching has been completed, is controlled to form a straight line or desired curve by servomechanism. In other aspects it is almost the same as the articulated switch.

o Scissors crossing

Scissors crossing is made by bringing free ends of four switches together as shown in Fig. 4-7-35.

As the gap between the free ends of two switches varies greatly depending on whether the switching is made for straight line or curved line, an expansion finger plate is to be used to fill this gap.

(8) Tunnel

Planning, construction method and other auxiliary facilities are to be the same as for the subways.

(9) Station

The elevated type is the standard. The platform is supported by cantilever beam with the utilization of pylon for track beam which is erected in the central divider, to make good use of open space over the road. However, in the section where runs in the track underground, the station is also to be an underground structure.

o Elevated station

To lead the passengers from platform to the side walk of the street generally, a bridge which is also used for pedestrians, provided below track beam. Examples of designs of elevated stations are shown in Fig. 4-7-36 through 43.

The following items are to be considered as station facilities.

(a) Platform

Because of such merits as a smooth track alignment, possibility of separating passengers by destination, low construction cost of station structures and convenience in extending the platform corresponding to the future increase in the length of train formation, the separate platform system is to be employed except in the case in which the number of passengers is too large to be handled with this system. Platform is to be of thin reinforced concrete slabs in combination with steel keystone plate to make the strucutre lighter in weight. The length of platform is to be the length of train plus 10 m as in the case of subways.

However, in consideration of the increase in the length of train formation in the future it is a devisable to provide additional pylons, one span length at both ends of platform, which may also be used for platform bearing pylon.

To prevent the fall of passengers, steel fence is to be provided around the platform except the track side, and steel gratings are to be provided below gap of track beam and platform. Though the width of platform is determined according to the number of passengers, the pylon for the platform should be of the design which enables expansion up to 5m in the future in consideration of the increase in the number of passengers.

(b) Roof of platform

Roof of platform is to be constructed of light gauge steel and is to be of the length 1/2 of the length of platform.

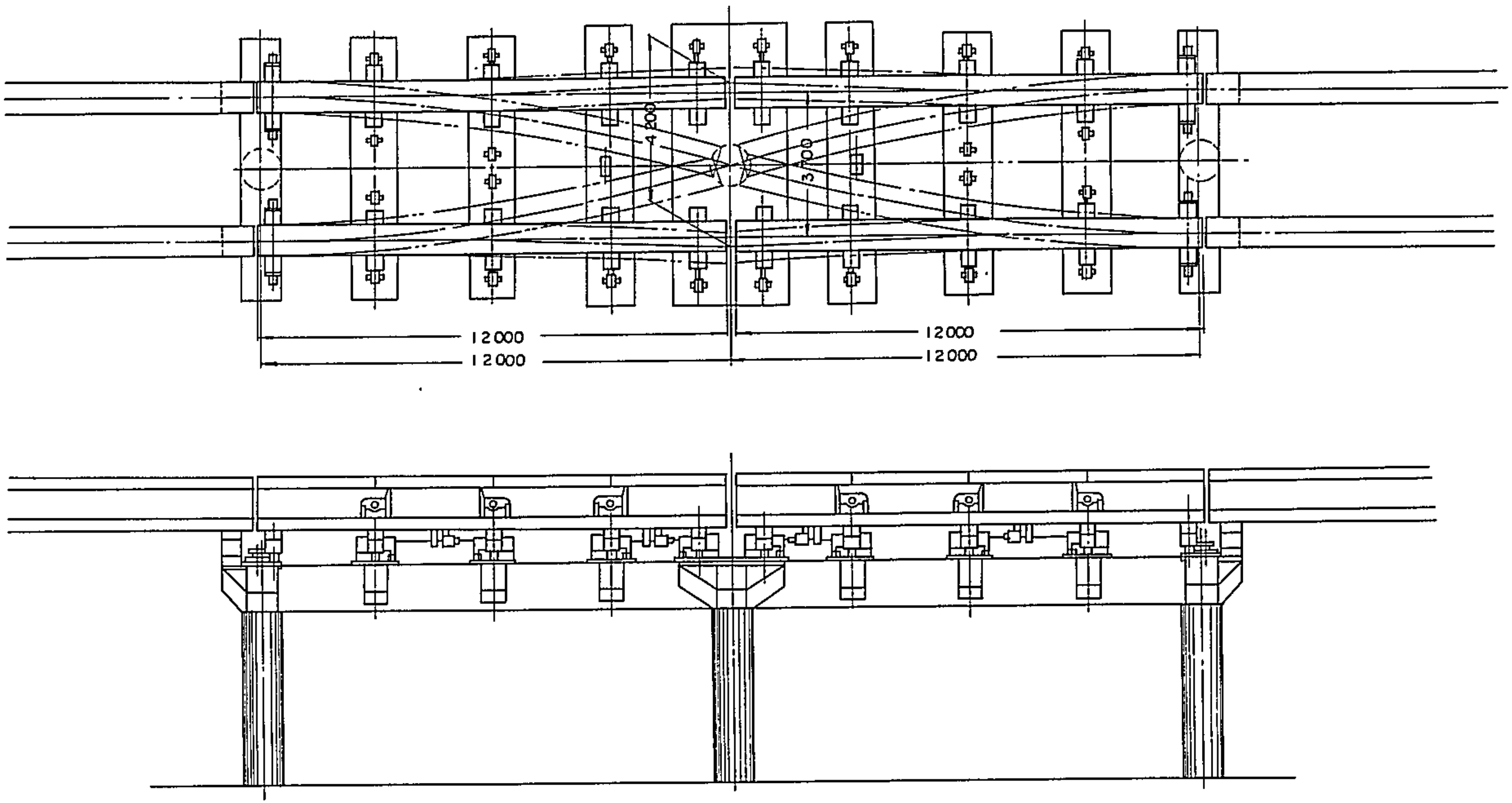


Fig. 4-7-35 General view of the scissors crossing

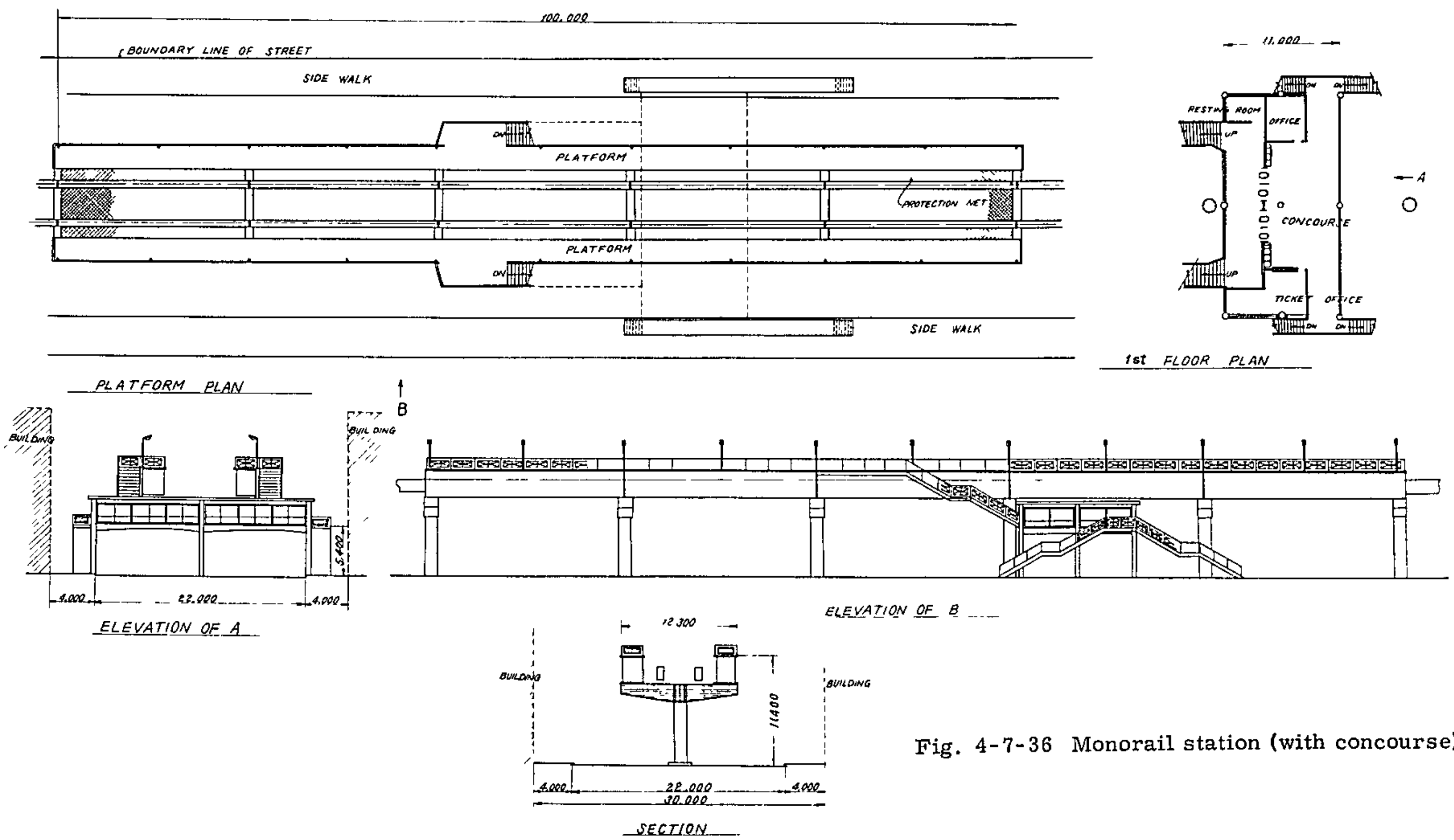


Fig. 4-7-36 Monorail station (with concourse)

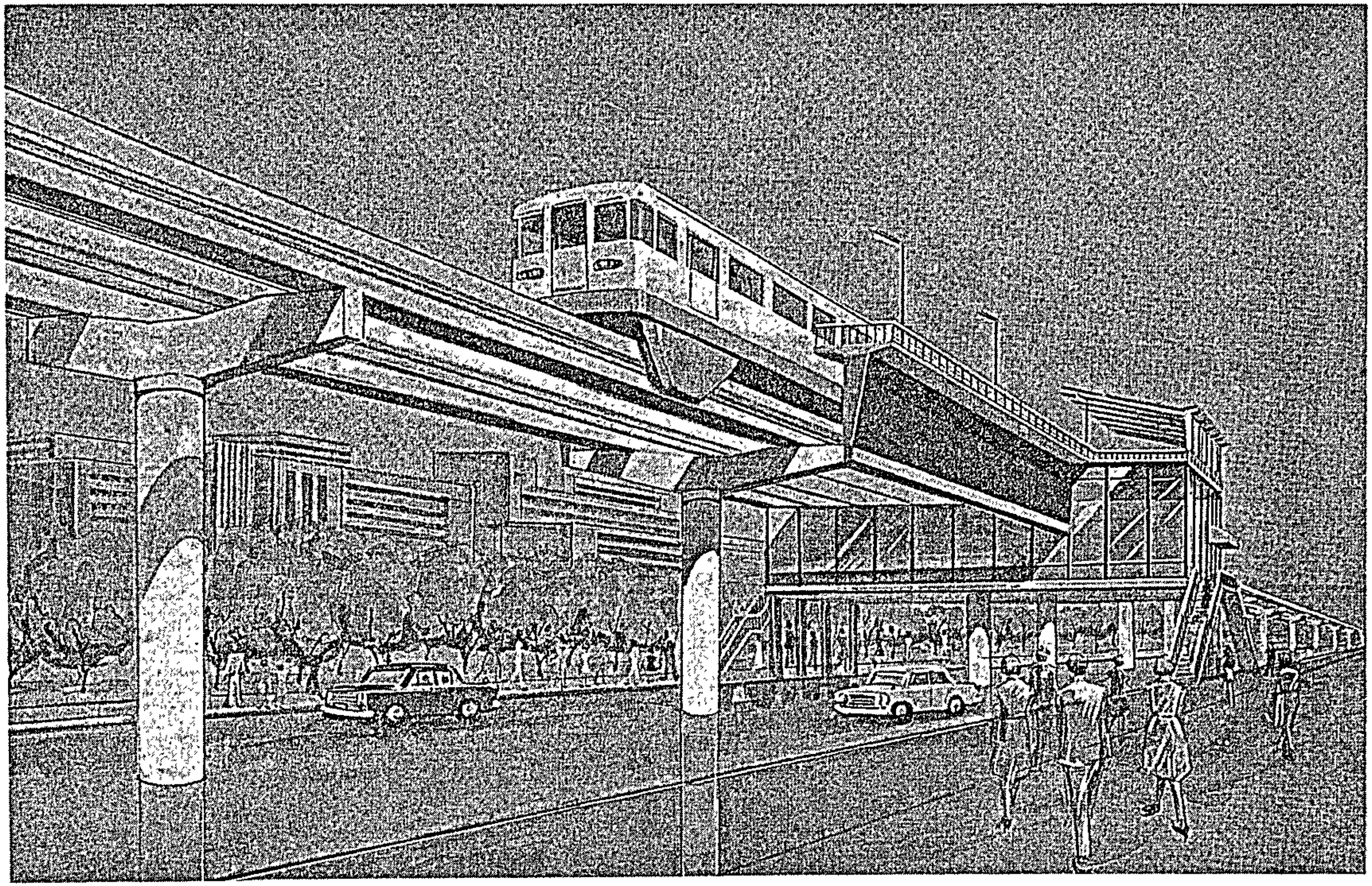
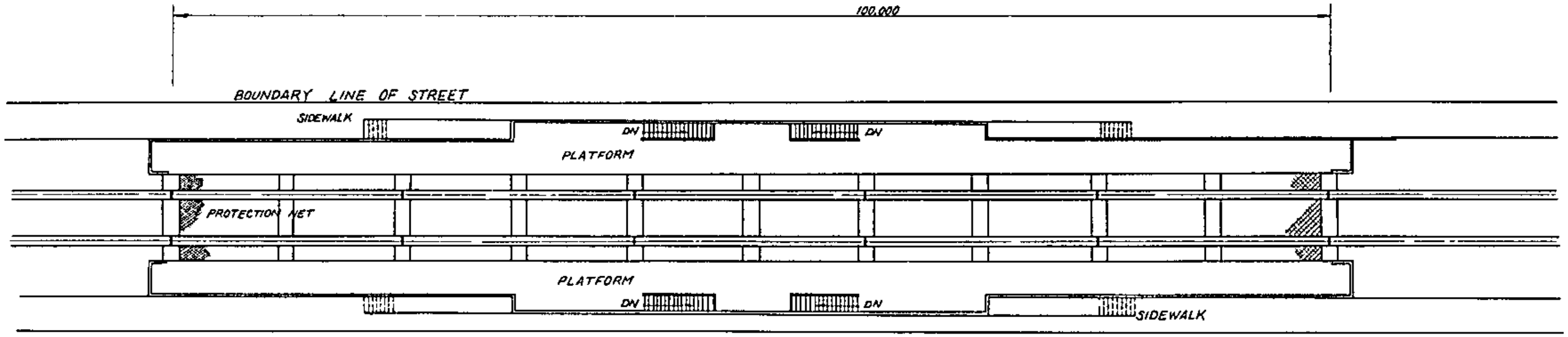
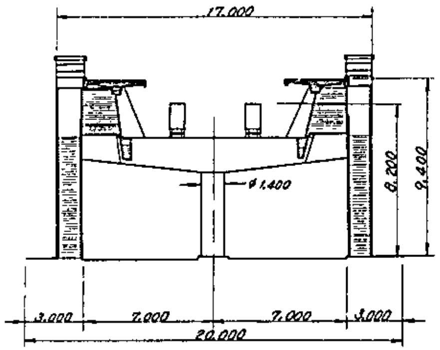


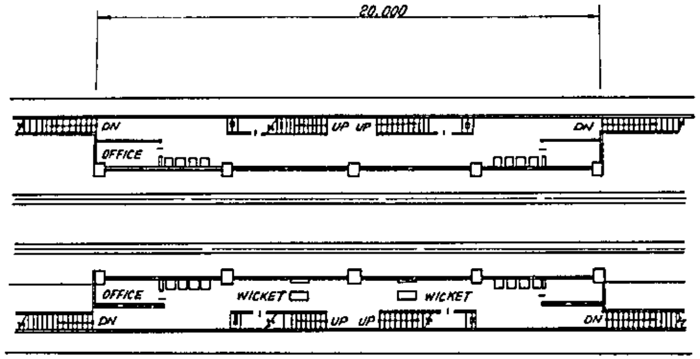
Fig. 4-7-37 Perspective drawings of monorail station
(with concourse)



PLATFORM PLAN



SECTION



1st FLOOR PLAN

Fig. 4-7-38 Monorail station (without concourse)

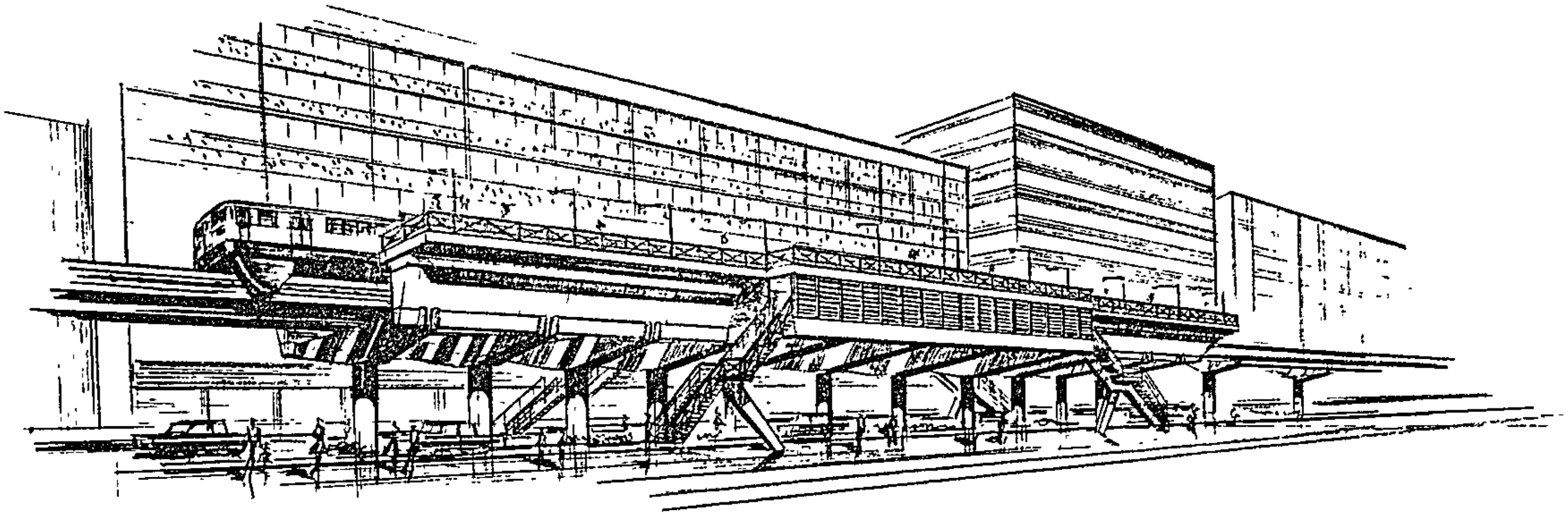


Fig. 4-7-39 Perspective drawing of monorail station (without concourse)

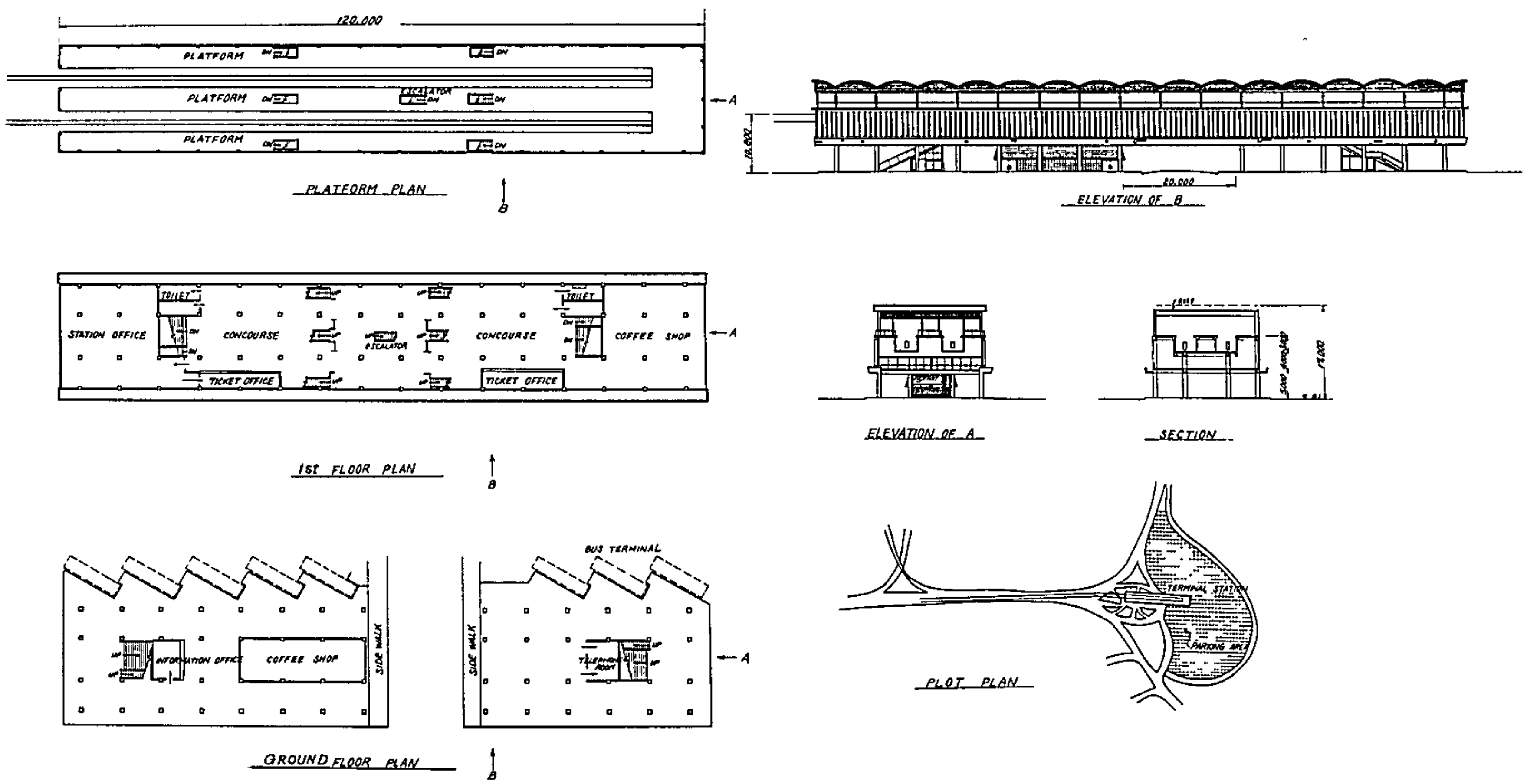


Fig. 4-7-40 Monorail station (terminal)

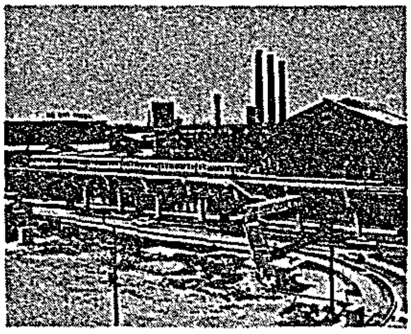


Fig. 4-7-41 An example of intermediate station (Haneda-monorail, Japan)

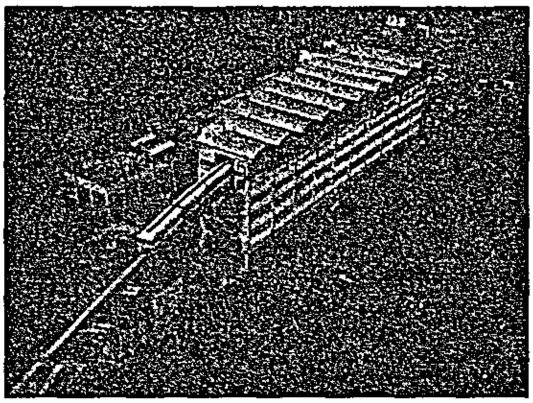


Fig. 4-7-42 An example of terminal station (Haneda-monorail, Japan)

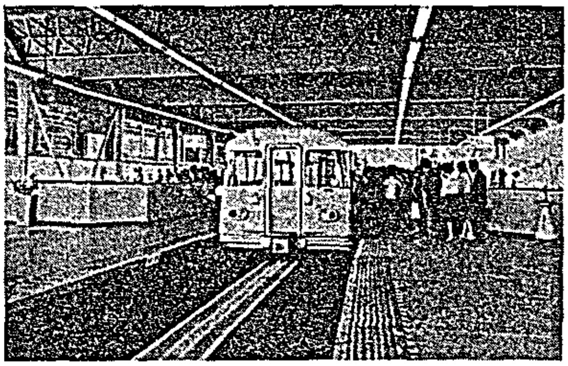


Fig. 4-7-43 Inside view of terminal station

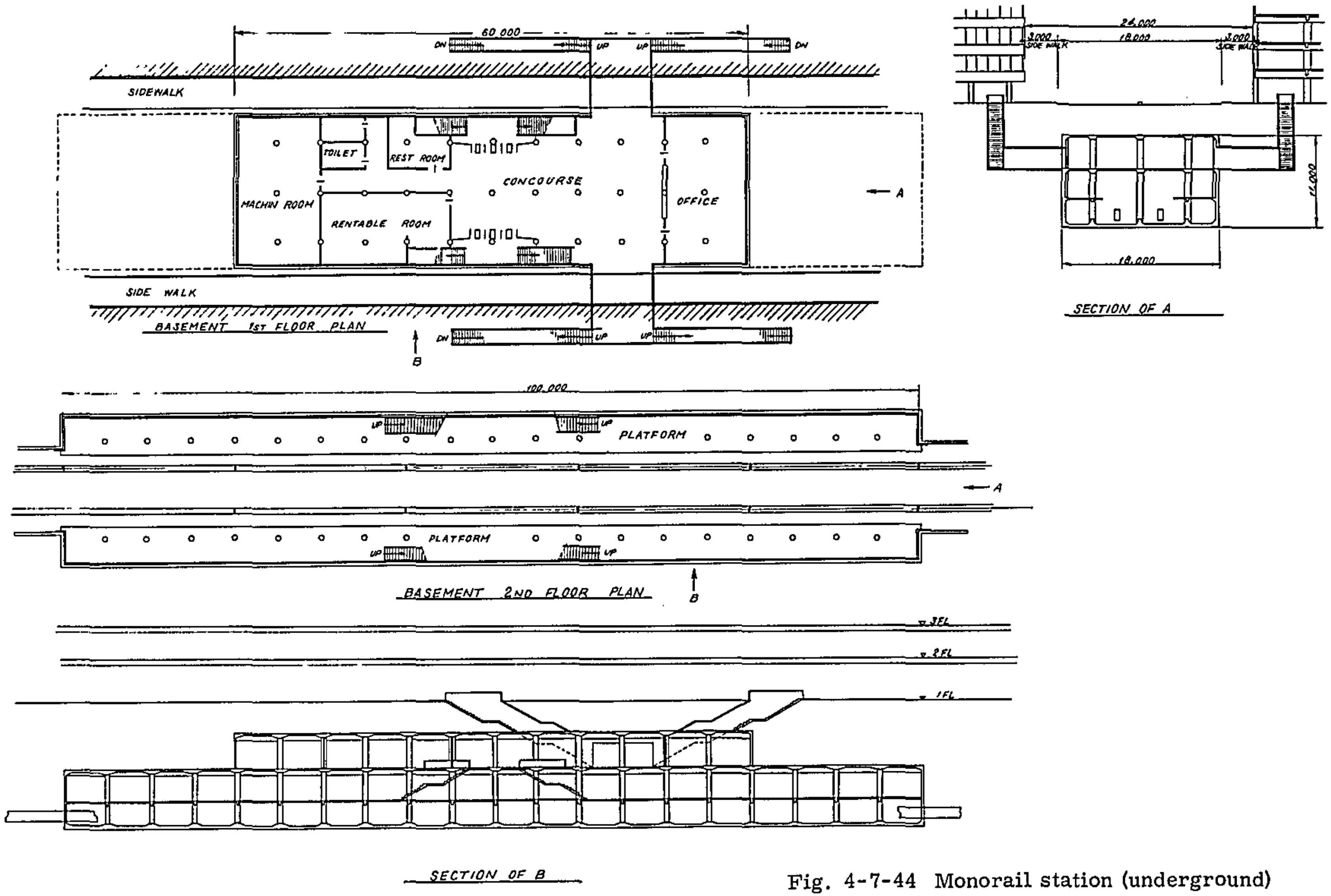


Fig. 4-7-44 Monorail station (underground)

(c) Stairway

For the station having a concourse as shown in Fig. 4-7-36, the stairway is to be connected from platform to the concourse which is provided below track beam across the street and a narrow stairway about 1.5 m in width is to be provided between the concourse and side walks, and should be considered to prevent congestion in the sidewalk. For the station with a large number of passengers, the width of the concourse is to be broadened and additional stairways are to be provided. Depending on the station site, it is sometimes more effective to provide entrances and stairways in the adjoining building and connect them to the platform with a walk bridge.

(d) Concourse

A concourse is to be provided in the vacant air space below track beam. The width of concourse is to be sufficient for providing a booking office and wickets and other necessary facilities according to the station size. The way is to be open to the public, and is also to be used as over bridge for pedestrians to cross the street.

(e) Booking office and wickets

Facilities are to be those required for the Token system in the same way as for the subway.

(f) Others

Broadcasting room, station office, signal room, electricity room and lavatory are provided according to the station size as for the subway.

Underground stations

In the underground section, the underground station is built in the same as for subway except the difference of track section. Examples of monorail underground station are shown in Fig. 4-7-44 and 4-7-45.

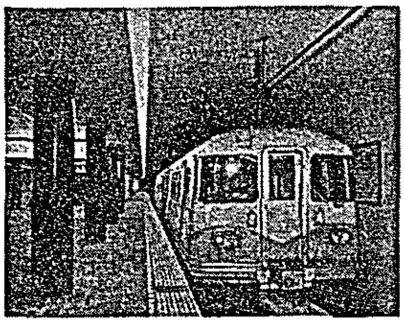


Fig. 4-7-45 Underground terminal station (Haneda Airport, Japan)

(10) Car sheds

For accommodation, inspection, washing and repair of cars, there must be at least one car shed for each route. The location of car shed must be selected by taking into consideration the location condition and convenience in the operation of cars. In the car shed, checking and inspection of cars have to be carried out daily, monthly, yearly and at intervals of third-years.

Main buildings, yards and principal facilities in the car shed are as follows:

Buildings: *Shed where daily, monthly and yearly inspections are carried out.*

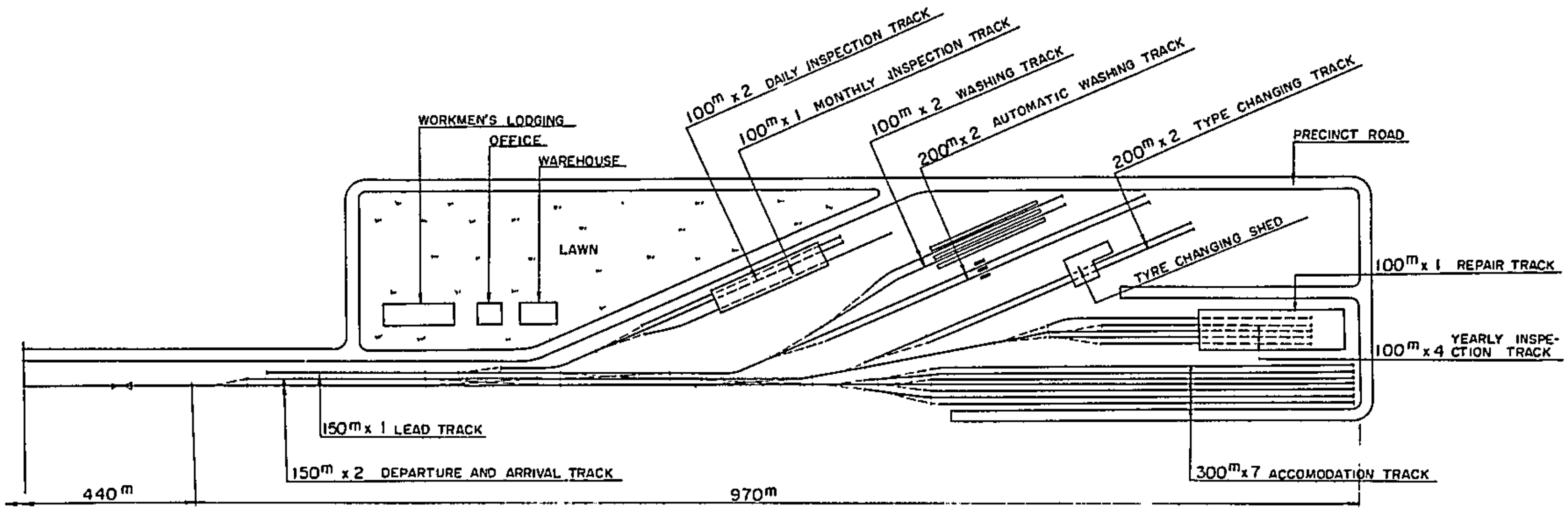


Fig. 4-7-46 Car shed (an example for 200 cars)

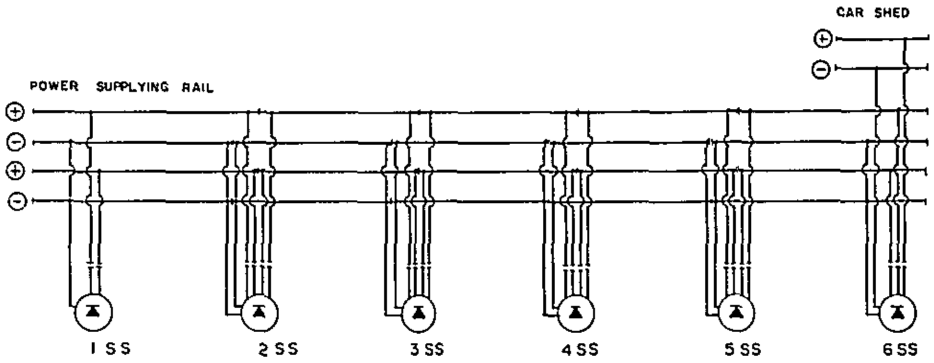
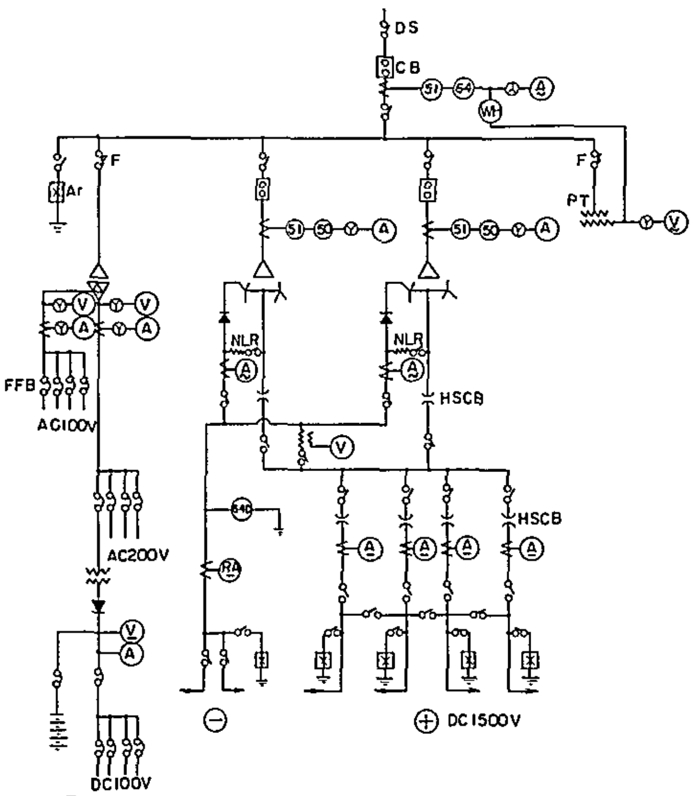


Fig. 4-7-47 An example of feeding system

DEAD SECTION
H S C B



SILICON RECTIFIER
O RELAY & METER
DS DISCONNECTING SWITCH
CB CIRCUIT BREAKER
HSCB HIGH SPEED CIRCUIT BREAKER
NLR NONLOAD RESISTER
Ar ARRESTER
FFB FUSE-FREE BREAKER
F FUSE
BATTERY

Fig. 4-7-48 An example of single line drawing of substation

Buildings: Shed where tyres are exchanged and bogies are remounted from a car.

Shed where car parts are inspected and stored.

Office and warehouse.

Yards: Car washing yard, daily inspection yard, car accommodation yard, entry and exit yard.

Principal facilities: Automatic car washing machine, Electric air compressor

Device for removing a bogie and device for suspending a bogie
3 ~ 7 t cranes, forklifts

Bogie supporting stand, running wheel axies stand, temporary bogie

Reduction gear washing facilities

Resistor *washing facilities, hot air drying facilities*

Tools, machines, work-stands cab signal system testing facilities, direct current supplying apparatus, electric charging apparatus

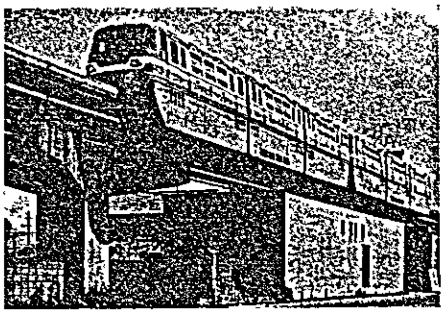
Fig. 4-7-46 shows an example of car shed layout for accommodation of 200 cars.

(11) Power supply system

Main power source

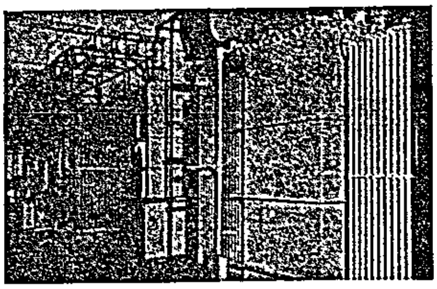
Output voltage is to be 1500 V. The electricity required is received at the substation from an electric power company in the system through the three-phase A.C. At the substation the A.C. is regulated to desired voltage and after being rectified by silicon rectifier the DC is taken out and supplied to the supplying rail. Though there is a requirement for some spare rectifiers, this requirement may be eliminated by mutual substitute when many substations are provided along the track. These equipment must be of the type which are fully capable to bear overload during the operation of trains. Fig. 4-7-47 shows an example of feeding system. The figure shows that the (+) side power is supplied separately to the up line and down line as well as to the left direction and to the right direction. The (-) side power is connected separately to the both directions, left and right. Independent system is to be provided for feeding of power to the car shed.

DC circuit breaker is to be provided on the (+) line at the outlet of substation to cut off fault current quickly in case of earthing or short-circuit of outdoor feeder line for the protection of substation equipment. Fig. 4-7-47, 4-7-48 show an example of the connection diagram at the substation. In this case, two sets of main transformers are provided. A.C. of low voltage for the use at the substation and DC 100V for control of substation equipment are taken cut separately. Not every substation is manned but is watched and controlled remotely from a single control center. Fig. 4-7-49 through 51 show examples of Haneda Line of Monorail.



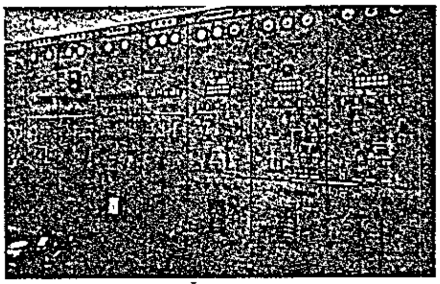
The Shinagawa substation is constructed underneath the line track beam

Fig. 4-7-49 Shinagawa sub-station (Haneda-monorail, Japan)



In the foreground: transformer for the silicon rectifiers, receiving transformer, extra high tension receiving apparatus.

Fig. 4-7-50 Showajima sub-station apparatus (Haneda-monorail, Japan)



Four panels on the left are for the control of Showajima substation, four panels on the right are for remote controlling of Haneda, Katsushima, Shinagawa and Hamamatsu-cho substations

Fig. 4-7-51 Showajima sub-station control pannel (Haneda-monorail, Japan)

Auxiliary power source

Low voltage AC and DC power sources are to be provided for various equipment and for lighting in the substation. The power required for such operation-related facilities as station buildings, car shed and signal room is to be supplied directly from a nearest electric power company.

(12) Power supplying rail and earthing plate

To supply the running car DC 1500 V power, the power supplying rail is to be installed along both sides of track beam as shown in Fig. 4-7-52 and Fig. 4-7-19, that is, one side is for the (+) side power supplying rail and the other side is for the (-) side power supplying rail.

Both (+) side and (-) side supplying rails are to be supported and insulated from track beam by insulators. The standard supporting distance is to be 2.5 m and rails are supported in such a way as to prevent their expansion or contraction due to the outdoor temperatures. The joint of the rail is to be electrically connected with a bond. For power supplying rail, hard copper conductor of 100 mm^2 gauge is to be attached on the aluminum supporter having a T-section. The (-) side power supplying rail is to be earthed at the substation but the (+) side power supplying rail, because of high voltage, is to be provided with insulating

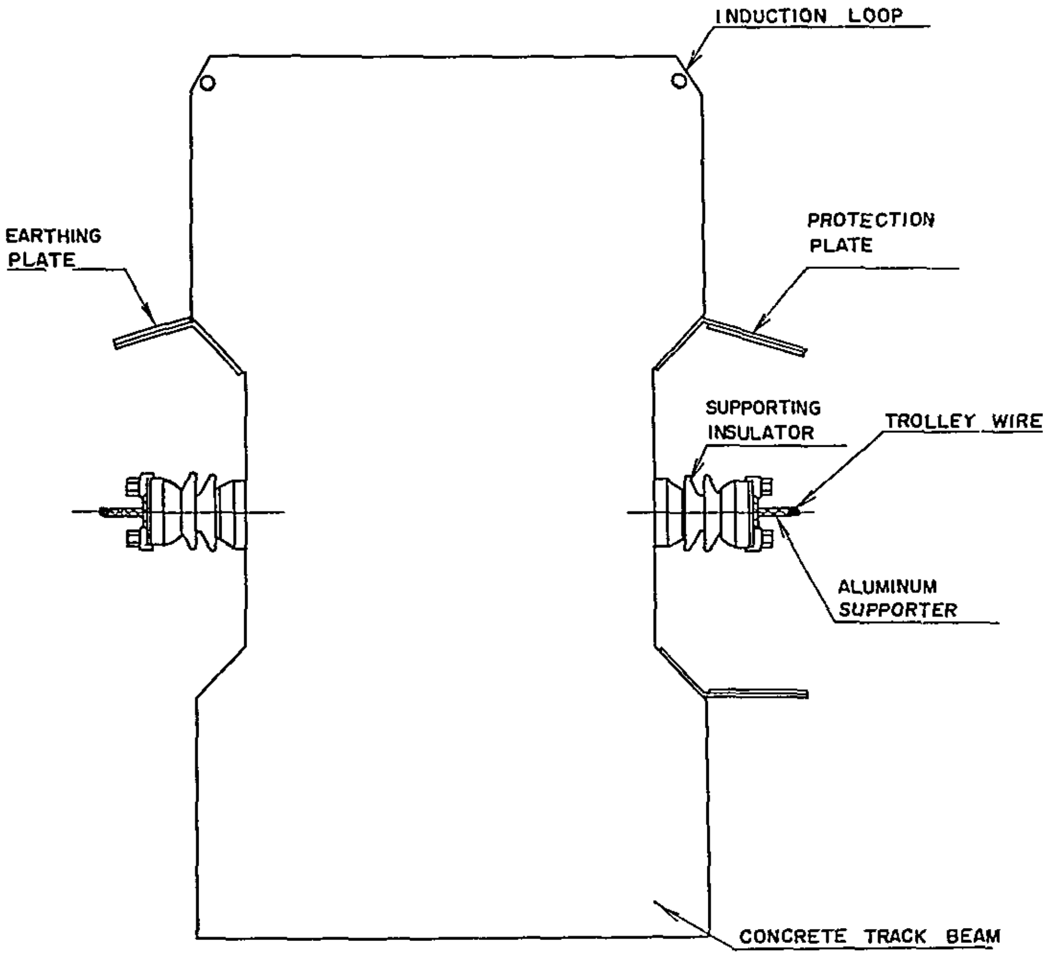


Fig. 4-7-52 Installing of electric power supplying rail and earthing plate

protection plate where people are likely to touch such places as along the platform or the fixture at the height less than 5.0 m above ground. Protection plate is to be fixed rigidly with metal fittings. For the rail installed at the height less than 3.5 m, protection fence must be provided to prevent accidents. As rubber tires are employed as wheel, the car body is insulated from the ground electrically. As a result, accumulation of electric charge in the car during operation is very probable. To prevent the accumulation of electric charge in the car and to eliminate to discharge of the accumulated static electricity through the bodies of passengers when entering or leaving the car, a metal earthing plate is to be provided above the (-) power supplying rail as shown in Fig. 4-7-27, with which the earthing device of car body makes contact to discharge accumulated electric charge. Earthing plate is to be fixed rigidly on the track beam with metal fittings.

(13) Auxiliary power facilities

Power room for each station, illumination of tunnel, drain pump, ventilators and station lighting facilities may be handled in the same way as for the subway but the signal power source in the case of monorail is not required for each blocking section along the track and therefore high tension power transmission line is not to be provided and instead the power for each station and car shed is to be supplied directly by the electric power company as described in 4.7.5 (11).

(14) Signals and safety facilities

To ensure safe and precise operation of monorail system, signals and safety facilities are to be installed with the following three aims;

1) To maintain a prescribed distance between trains to protect from collisions

2) To have trains traveled along designated routes by interlocking switches and signals

3) To prevent derailment both at the ends of tracks and at the switch

To accomplish these aims, automatic blocking signal equipment for item 1), relay interlocking equipment for item 2) and automatic train stopping equipment device for item 3) are to be provided.

o Automatic blocking signal equipment

The blocking signal equipment is made up of two sections, i.e. the blocking system and the signal indicating system. Blocking method is to be automatic blocking system and the signal indication is to be of cab signal system.

In order to maintain the prescribed minimum distance between trains, blocking sections are to be successively incorporated on the track so that the position of trains may be checked and the signal indicating the allowable speed may be given to the succeeding train depending on the distance between the two trains. When the succeeding train approaches too close, the equipment according to the distance gives a slow down signal or a stop signal to the train.

All equipment are to be housed in the equipment room at one location as practically as possible to insure easy maintenance but signal receiving circuit, ground antenna, matching device and pre-emplifier are to be provided along the track and connected to the central equipment room by signal cable. Cables are to be housed in the rack provided directly under the track beam. In the underground section, cables are to be provided on the side wall of the tunnel.

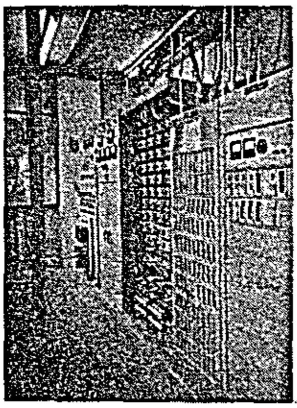


Fig. 4-7-53 Signal apparatus room

Fig. 4-7-53 shows an example of equipment room layout. Principles of automatic blocking system and cab signal system will be discussed later.

Relay interlocking system

This system controls the operation of train and switch by interlocking the opening direction of switch with signal indication or by automatically detecting whether the train is near the switch or not, and it consists of mainly the relay and operating boards. This equipment is installed stations in which switches are equipped.

o Automatic train stopping equipment

An automatic train stopping equipment is to be provided this side of the end of track or switches where there is a possibility of derailment as a result of over-run of train. If the driver ignores signal indication and advances the train to this point, the equipment immediately checks the position and speed of train and the condition of switch irrespective of the will of driver and stops the train automatically.

The principles of automatic train stopping equipment will be given at a later stage.

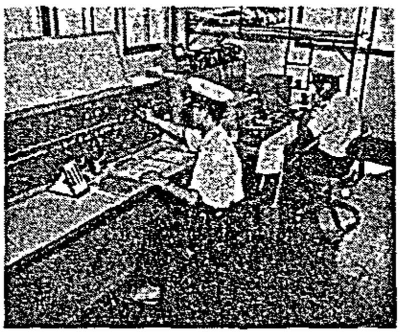


Fig. 4-7-54 Control room (Haneda-monorail, Japan)

Central train watch and automatic train control with the installation of the above signal and safety equipment and with the help of lamps which light up on the train indication board in the control center, centralized surveillance over the movement of trains is more effectively accomplished.

Fig. 4-7-54 shows an example of control center layout.

Also, by interlocking the signal given to the train according to the speed with the automatic train control equipment, operation of train may be controlled automatically without difficulty.

o Principles of automatic blocking system

Blocking system is to be the fixed blocking system as in the case of the existing railways and each blocking section is to be the so-called automatic signal system which changes signal one after another as the train proceeds.

To change signals in the rear of the train by the movement of train in this way, it is necessary to detect from the ground whether a train is on a blocking section or not. As the monorail train travels on the concrete track beam with rubber tires, the conventional detection method, through the short circuit of iron rails, so far used by the railways cannot be adopted. Therefore, in the monorail system, train detection is connected through the so-called "check-in, check-out" system, under which signal radiating apparatus are installed on the lead car and the tail car of a train, and special apparatus are installed on the ground at the edge of each blocking section or a part of route section to receive signals and count the number of trains which enters the section and leave it.

For the detection of train, high frequency electric current is fed into the cab transmitter, i.e., check in frequency for the lead car of the train and check-out frequency for the tail car. When the ground antenna installed beneath the track beam receives either check-in or check-out frequency through induction loop the counter circuit is actuated through relays. The principle of this system is given in the upper half of Fig. 4-7-55.

With reference to Fig. 4-7-55, when the train proceeds in the direction of arrow, the ground antenna Q1 provided at the entrance of blocking section or a part of route section receives check-in frequency "f", from the apparatus of the lead car of the train and the counter circuit"c" is actuated through receiving circuit "R1", and registers "count 1" (the existence of one train).

In this way, the "T" portion is able to detect the train in the same manner as the rail short-circuit system. When the train proceeds further and the transmitter installed at tail car of the train passes over the ground antenna Q at the exit of blocking section or the portion of route section"T", through the check-out frequency "f'" and section "T" the counter circuit "c" registers "count 0" (no train existing). In this way, the departure of train from section "T" may be detected. By using plural ground antenna for the common use of chek-in frequency and check-out frequency, it is possible to detect of trains in several continuous sections. By reversing the input of each frequency to the counter circuit, train detection in ther reversed directivity is possible. The principle of this system is given in the lower half of Fig. 4-7-55. Where the directivity of trainiis prescribed at such section as double tracks, the circuit is to be made to have only the required directivity from the beginning. Though the capacity of counter circuits for "0" and "1", which means "the non-existence of a train" and "existence of one train", but in the sections of high density of train operation, counter circuits are devised to register "count 0", "count 1" and "count 2", i.e., "the non-existence of a train", "the existence of one train", and "the existence of two trains", thus enabling the existence of two trains in one blocking section. According to the condition of this counter circuit, the signal indication to the succeeding section changes automatically. Check signals are sent to the ground antenna constantly to find out if it is in proper working order.

o Principles of cab signal system

It is common with conventional railway system to use on the so-called ground signal system, which shows green, amber and red signal lamps indicating "clear", "caution" and "stop" respectively as signals installed on one side of track

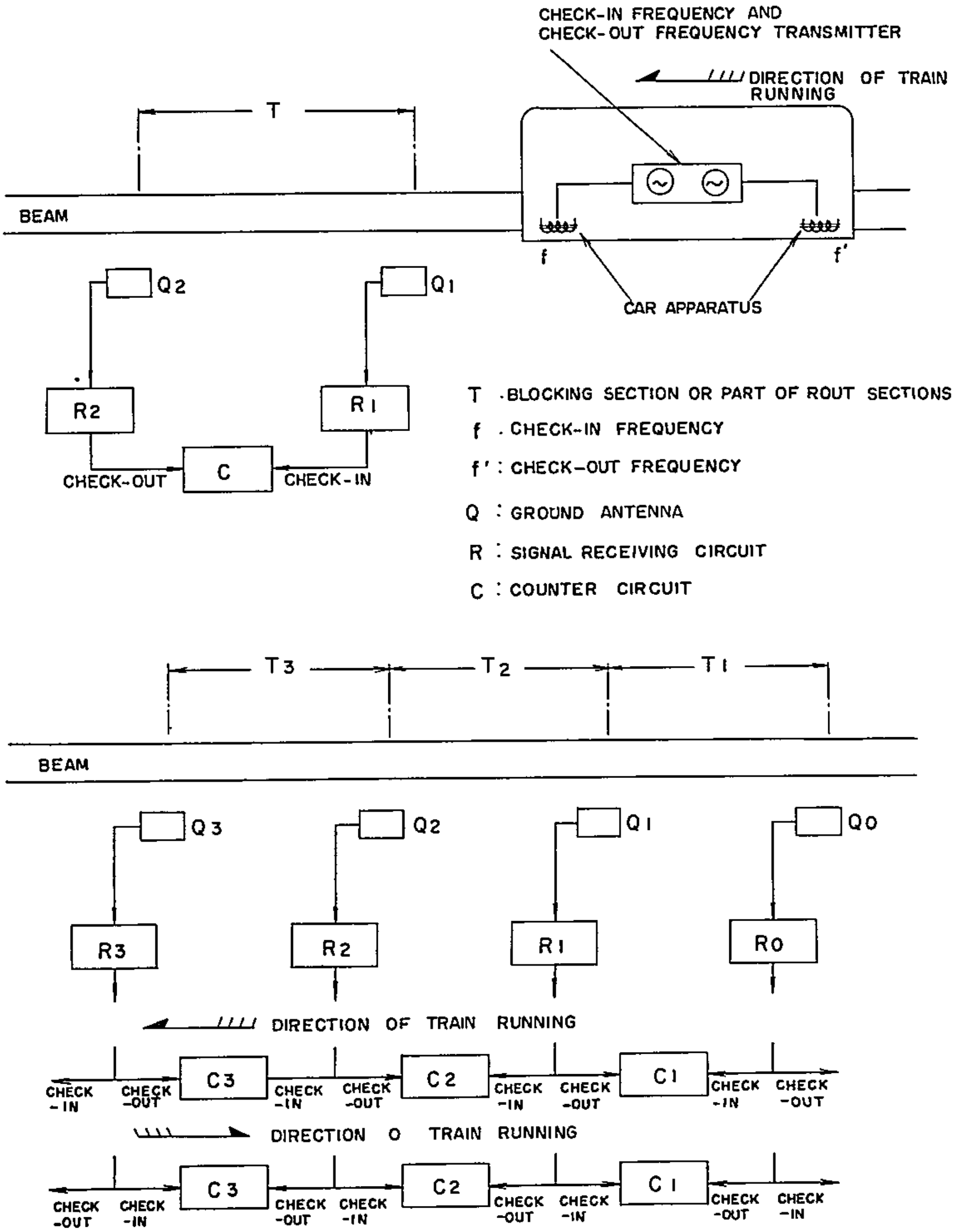


Fig. 4-7-55 Principle of blocking system

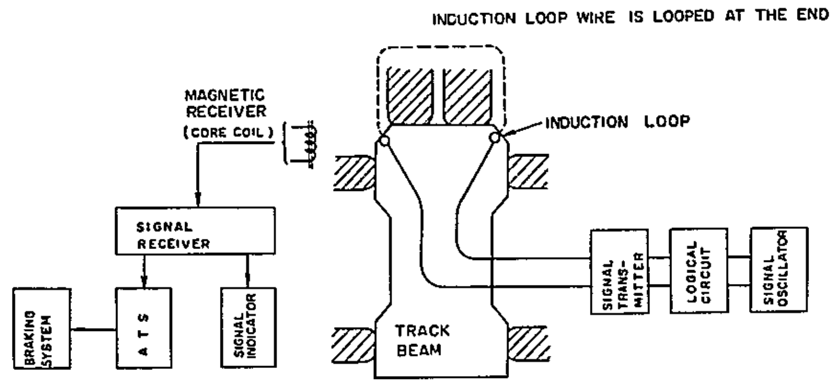


Fig. 4-7-56 Principle of cab signal system and ats system

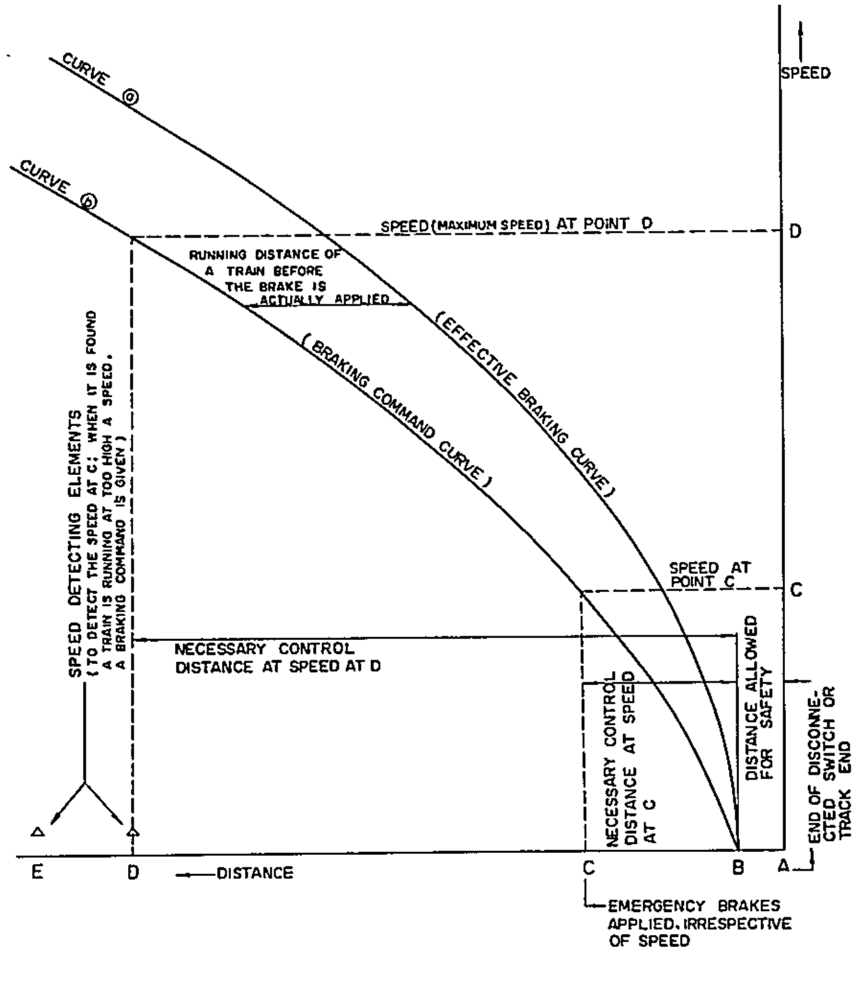


Fig. 4-7-57 Principle of over-run protection system

at the entrance of each blocking section. However, with the Alweg monorail system for urban transport purpose, installation of such ground signal apparatus to the track involves extreme difficulty for the maintenance of apparatus due to the design of track structure. Besides, it will be extremely difficult for the driver to distinguish signal indication from other illuminations such as neon signs in the towns and the presence of signal apparatus is not advisable from the standpoint of maintaining the beauty of the city. Therefore, in monorails, these indicating lamps are all accommodated in the driver's cab of a train, i.e., the so-called cab signal system.

Fig. 4-7-56 shows the principle of cab signal system. On the ground the devices consist of oscillators, logical circuits, transmitters and indication loops, etc. On the cab, the devices consist of magnetic receivers, a signal receiver and signal indicators, etc. There are special induction loops incorporating special conditions involving switches and departure and arrival track in the car shed, etc., in addition to the induction loop for the automatic blocking section. To each signal induction loop, appropriate signal current is supplied from the transmitter, through the operation of a logical circuit according to the conditions of counter circuit in the automatic blocking section or special conditions existing in each section. This signal current is received by mangetic receiver and is transmitted to cab signal apparatus through signal receiver to indicate a signal. If ATS system is connected to the cab signal receiver as shown in Fig. 4-7-56, automatic train stop system is easily operated, interlocking with the signals indicated on the indicator. In other words, when the stop signal is indicated, the cab signal receiver transmits a signal to ATS system and braking apparatus is actuated.

An example of signal indication is shown in the following.

Table 4-7-2 Kinds of Signal Indications

Mark of Signal	Cab signal indication	Meaning	Remarks	ATS operation
G	Green lamp x 1	Clear		
YG	Amber lamp x 1 Green lamp x 1	Reduce speed	Bell sounding	
Y	Amber lamp x 1	Caution	"	
YY	Amber lamp x 2	Warning	"	
R	Red lamp x 1	Permission stop	Buzzer sounding	Emergency brake to be applied after 5 seconds
RR	Red lamp x 2	Absolute stop	"	Emergency brake applied immediately
Z	White lamp x 1 Red lamp x 2	Call-on		
UB	-		Release from "R" signal interlocking	

o Principles of over-run protection system

To stop the train safely against track end or the end of disconnected switch, the train must be controlled further than the necessary control distance.

In Fig. 4-7-57 the effective stopping curve required to stop the train at point "B" and the braking command curve which gives a command to the train to apply a brake making allowance for the distance which the train runs before the brake is actually applied are shown by curve (a) and curve (b) respectively. Theoretically, the train receives the braking command at a point on curve "(a)" and reduces its speed along curve "(a)" until it stops automatically.

In giving a braking command to the train, it is ideal to be controlled of continuously in receiving a braking command like curve (b) but in practice it is simplified and the control is exercised at the points. In that case, the control points are classified into the following two points;

(1) Point where brakes are to be applied irrespective of speed of the train

(2) Point where decision is to be made for applying brakes in accordance with the speed of train

In the figure, the point described in Item (1) is point C and the point described in Item (2) is point D. The point A is the end of disconnected switch or a track end and the distance between point A and point B is the distance allowed for safety, where a shock-absorber is to be provided.

When the speed at point C is fixed, the required distance between points B and C is also fixed accordingly. Usually the distance between points A and C is first determined from existing condition, from whcih the speed at point C is calculated. Generally, the speed at point C is more than 10 km/h and the distance between points A and C is fixed to be 20 to 40 m. When a train passes beyond point C an emergency brake is to be applied unconditionally so that the train may stop at point B or before the point.

Point D is determined by making the distance between points B and D as the required control distance when the speed of a train is physically highest (or the maximum allowable operating speed). At this point it is necessary to detect the speed of train and the speed is generally detected by its speed at point C. In this case, when the speed at point C is hinders normal train operation, the number of point D may be increased to multiply detection of train speed so that the speed at the distant point may be increased gradually. For the detection of speed, speed detection elements are firstly installed at points D and E. Then the average speed between points D and E is calculated by measuring the time required for a train between points D and E. In practice, the distance between points D and E is decided, in such a manner that the time required for the train to pass the distance between points D and E may be two seconds. By this, the train passing the distance between points D and E in less than two seconds is considered to be running at too high a speed and is given a braking command.

According to the place where the above two seconds will be checked the system is devised into two types, i.e., the ground checking type and the car checking type. The car checking type is used mainly for the ground signal system.

The ground checking type is used mainly for the cab signal system and its method is to give a signal to the speed detecting elements by the check-in frequency from the car and checking is done on the ground. The result of time checking is conveyed to the logical circuit as shown in Fig. 4-7-56, and the signal of the inducting loop is changed when it is found that the speed of train is too high.

For the protection at disconnected end of switches taking the signal in the compound or the proceed signal as point A the distance between points A and C is to be made as long as possible under the existing condition. When the advatageous route is made up by relay interlocking system, its ATS function is to be made non-operative.

Example of the signal system

An example of the signal system so far described is as follows:

Blocking system; Check-in, check-out fixed blocking system

Signal indication system; Cab signal system

Relay interlocking system; Electric relay interlocking

Automatic	Type		Continuous control type
Train	Speed detection		Ground checking type
Stop	A.T.S. operation	Signal R	Emergency brakes after 5 seconds
		Signal RR	Emergency brakes instantly
		When passes point "C"	Receive RR signal
		When passes point "D" at too-high speed	Signal of induction loop made RR by ground checking

These equipment incorporate a Fail-Safe system which goes into action immediately it detects an abnormal situation. Since the number of brocking, the contents of signal indication, or the installation of A.T.S. varies according to the conditions of the track and the operation, each concrete case must be examined, taking its condition into consideration.

Automatic operation

Though additional equipments are required in the car and on the ground for the automatic operation of train, there is no specific problem involved.

(15) Communication facilities

1) For communication facilities, the railway telephone and train telephone are to be provided.

2) For the railway telephone, wire telephone is to be adopted and the following circuits are to be installed.

Train dispatching circuit: This circuit is used by operation dispatcher to give dispatch on the operation of train to signalmen or to communicate to station clerks. This circuit is also used for communication between signalmen and station clerks. For this purpose, train dispatching telephones are most suitable.

Business telephone circuit: For various business purposes, exclusive telephone circuit of the required number is to be installed. For this purpose, magneto telephones are mainly used. Railway telephone cables are to be installed in the racks provided beneath the track beam.

3) Train telephones are to be radio telephones. For this purpose, radio telephone facilities which use radio waves in the ultrashortwave band allocated by the Radio Regulatory Bureau. Talk system is to be the FM press-and -talk method.

The base station is to be established on the ground and moving stations on the train for regular and emergency communication between train dispatcher and the driver.

(16) Car

o Design criteria

Design criteria of monorail car is almost similar to that of the subway car. However, since monorail car travels the space over the road in the city area, elimination of noise problem is most important and for this reason, the car must be equipped with rubber tires to minimize noise problem. While the rubber tire eliminates the requirement for maintenance work such as calibration of wheel tread, which is customary with the metal wheel, it requires recapping when worn out and the frequency of removal of tire increases accordingly.

For this reason, removal of tires must be easily accomplished. As tires are installed between the car floor and the upper surface of track beam to bear the load of the car, attention must be paid to the design of car, otherwise the truck will have to be separated from the car body every time a tire is replaced. To insure easy removal of tires to separation of truck from car body, special measures including installation of trap doors in the car floor or employing overhung wheel axle must be provided.

Though a larger car body is desirable from the standpoint of transport capacity, the loading capacity of car is limited because of its rubber tire. Therefore, an attempt must be made to make the carbody as light as possible, and the car length should be slightly less than that of a subway car.

It must also be noted that the car body equipped with rubber tires is insulated electrically from the track. Therefore, adequate measures must be taken against the accumulation of static electricity, the possibility of earthing of high tension circuit and lighting.

o Outline

The type of cars are the electric car for the transportation of passengers and the internal combustion engine cars for track maintenance.

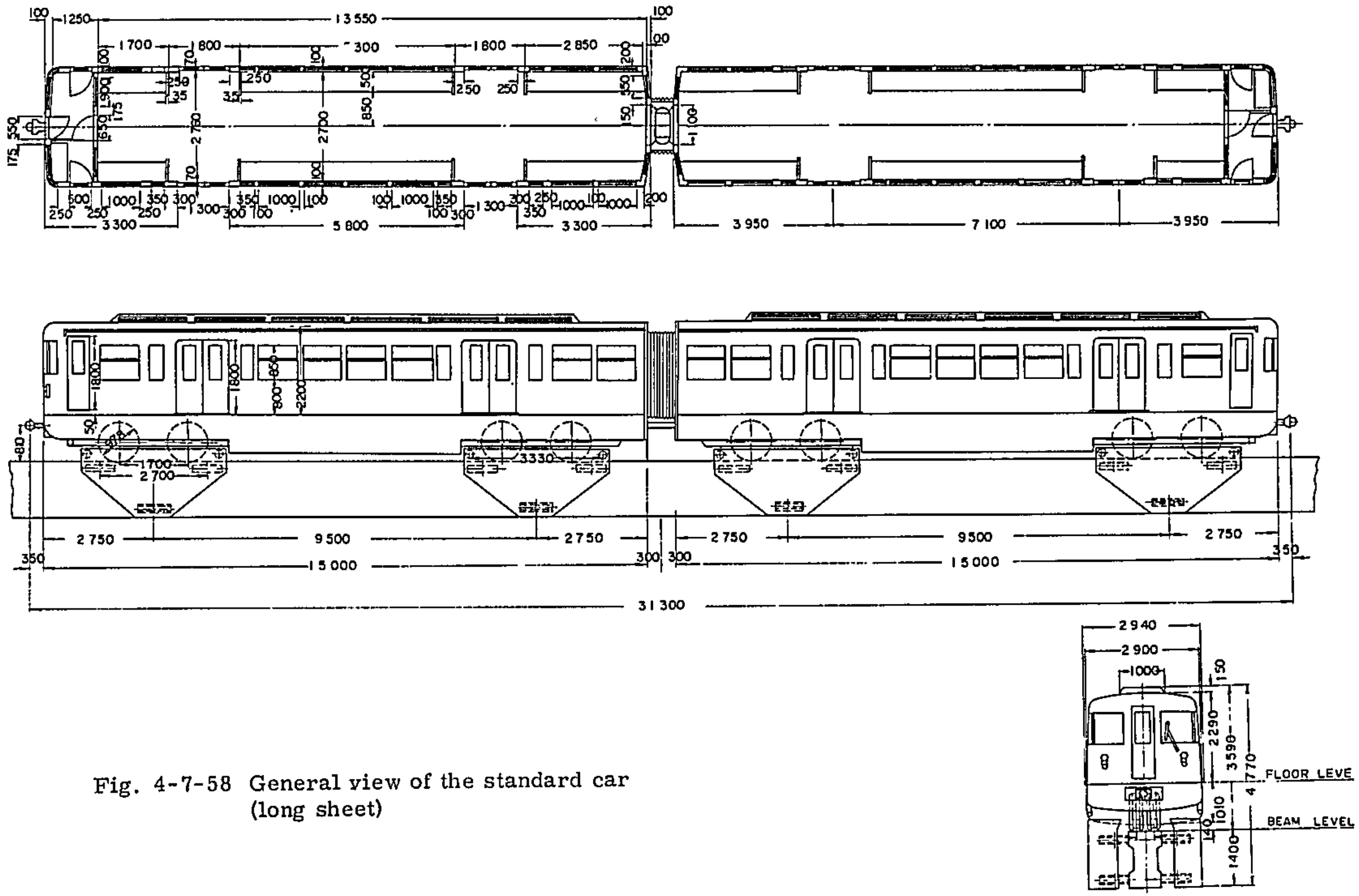


Fig. 4-7-58 General view of the standard car
(long sheet)

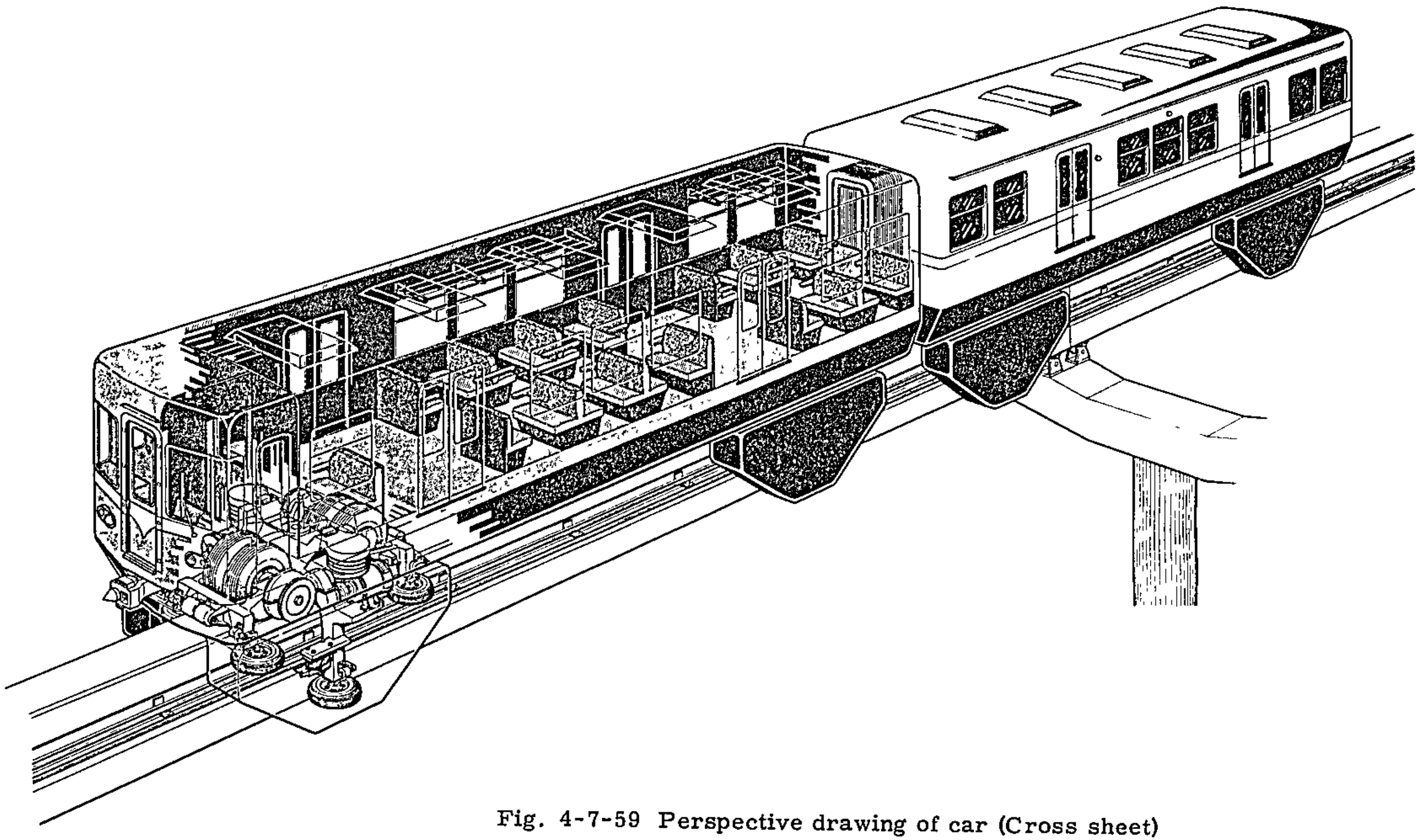


Fig. 4-7-59 Perspective drawing of car (Cross sheet)

The electric car is of 2-car permanent unit and the train is formed of 8-car for the maximum length is to be planned for normal operation. The car is roughly broken into the carbody and the truck which travels on the track beam supporting the carbody. Just like that of the conventional railway cars, a car is provided with two bogie trcuks. The inner floors of cars are completely flat.

Fig. 4-7-60 through 63 show examples of car design.

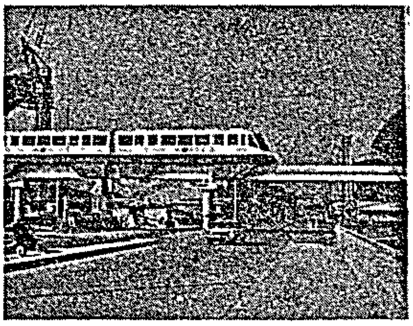


Fig. 4-7-60 Monorail-car (Osaka Expo' 70 monorail)

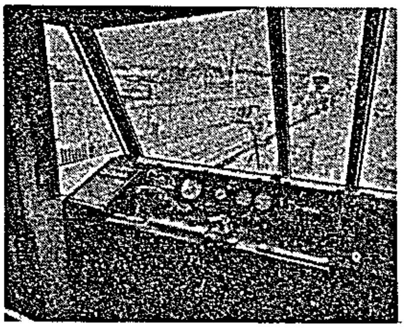


Fig. 4-7-61 Operating-desk of monorail-car

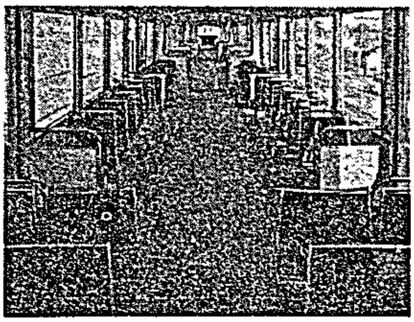


Fig. 4-7-62 Inside view of car (Osaka Expo' 70 monorail, Japan)

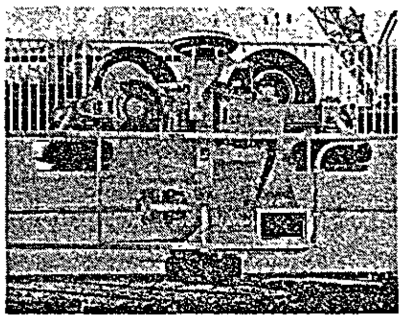


Fig. 4-7-63 Supporting apparatus

Electric car is driven by DC. and electric power is supplied to the car through the current collector fitted to the bogie. The current collectors collect the electric power from power supplying rail provided on the side of track beam and supply it to electric traction motors through the control equipment. The torque of electric motors is transmitted through the reduction gears to the vertical wheel which is contact with the upper surface of track beam and move the car.

The traction motors are installed on the bogie frame and the majority of other machines and equipments are rigged beneath the car floor.

Each bogie is equipped with six horizontal wheels to maintain stability of car and to guide the car along the track beam, and these wheels are pressed against the side of track beam by the flexure of the tires.

Braking system includes the spring brake for parking in addition to the electro-penumatic interlocking air brake.

Signal system is to be the cab signal system and a cab signal indicator is to be installed in front of the driver's seat. Automatic train stopping device interlocking the device with signals indicated is also to be installed to ensure the safety of operation.

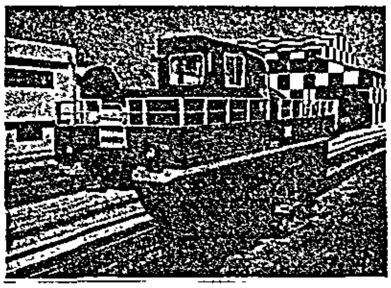
o Outline of specifications

(1)	Classification	Japanese straddle type monorail for urban transportation
(2)	Type	Electric passenger car with 2-axled bogies
(3)	Composition	2-car permanent unit
(4)	Voltage of power supply	D.C. 1,500 V
(5)	Straight acceleration	Approx. 3 km/h/s
(6)	Straight retardation	Approx. 4.5 km/h/s
(7)	Nominal max. speed	Approx. 80 km/h
(8)	Balancing speed	Approx. 90 km/h (with normal passengers, on level tracks, with rated voltage of power supplying rail)
(9)	Normal passenger capacity	130 (48 seated, 82 standees) per car
(10)	Full capacity	270 (48 seated, 222 standees) per car
(11)	Tare weight	Approx. 25t per car
(12)	Maximum dimensions	Length 15.65 m per car Width 2.94 m Height 3.59 m (above the beam)
(13)	Dimensions of structure	Length 15 m per car Width 2.9 m Height 3.3 m
(14)	Center distance of bogies	9.5 m
(15)	Rigid wheel base	Vertical tyre 1.7 m Horizontal tyre 2.7 m
(16)	Construction of car body	Welded metal construction (of steel make), light alloy plates used as part of skirt

(17) Interior	Aluminum plate covered melamine plastics, light alloy metal for curtain covers, etc.
(18) Doors	Two double sliding doors of light alloy per car at each side Automatic doors operated electro-pneumatically
(19) Windows	Upper halves slide down Lower halves slide up With roll-up type curtain
(20) Floor	Keystone plate covered with flexible vinyl plates No jutting wheel room
(21) Seat	Longitudinal seats covered with moquette or vinyl leather
(22) Hanging strap	Provided
(23) Parcel rack	Pipe-type fitted above the seats on both sides of the car
(24) Driver's cab	Provided on one end of each car, 2 cabs per unit Partitioned all round, with gangway and side doors
(25) Coupling device	Coupled end: Automatic tight coupler with electric and penumatic coupler Fixed end: Bar coupler
(26) Drafting device	Rubber cushioned draft gear
(27) Connecting gangway	Bellows-type
(28) Construction of bogie	2-axled bogie of welded steel construction
(29) Suspension device	Floating bolster, below type air spring, 2 sets/bogie, with height control valves, oil dampers and bolster anchors
(30) Axle of running wheel	Cantilever type hollowed axle with taper roller bearings Solid tyre type auxiliary wheel, 2 sets/bogie
(31) Vertical tyre	Rubber tyre sealed with nitrogen gas, 4 tyres/bogie Outer dia.: 978 mm Width: 350 mm Double wheel distance: 400 mm

(32) Horizontal tyre	Pneumatic rubber tyre, 6 tyres/bogie (4 upper guide tyres, 2 lower stabilizing tyres) Outer dia.: 730 mm Width: 205 mm Upper and lower: Wheel distance: 1,085 mm
(33) Axle for horizontal wheel	Cantilever type hollowed axle
(34) Guiding device	Direct pushing type
(35) Driving device	Right angle cardan device of two stage reduction
(36) Bogie brake	Disc-brake, 2 sets/bogie
(37) Parking brake	Cam type drum brake, 2 sets/bogie
(38) Current collector	Power supplying rail side contact type, mounted on bogie, 4 per train
(39) Auxillary electric source	A.C. motor-generator (or static inverter), with alkaline battery, floating charge type
(40) Main traction motor	Output: 65 kw, 8 per train
(41) Control device	Multi-control automatic acceleration and retardation type Multi-notch motor operated cam shaft controller with combined air brake and dynamic brake device
(42) Braking device	Electro-pneumatic straight air brake with load detectig device
(43) Sign device	Buzzer
(44) Speedometer	Electric speedometer
(45) Earthing device	Provided
(46) Ventilation	Axial fans fixed on the ceiling (provided as required)
(47) Heating device	Electric beaters fitted under the seat (provided as required)

An example of internal combustion engine cars for track maintenance is shown in Fig. 4-7-64.



It is a center-cab type, it has beam maintenance stands, water tank for washing power supplying rail insulators, sun visor projected antenna for radio telephone, magnetic receiver for signals, etc., and is not similar in appearance to an electric car

Fig. 4-7-64 Internal combustion engine locomotive

This engine car is generally used for inspection and maintenance of track and signal and communication equipment after the last train has left the scene. This car is also equipped with function and capacity to rescue passengers from the stranded train in an emergency such as power failure.

4.7.6 Operation plan

Operation plan of monorail system is shown in Table 4 7 3 below.

Table 4-7-3 Operating Speed and Running Time of Monorail

Items	Route 1	Route 2
Length of line	190 km	23.1 km
Number of stations	21	21
Average distance between stations	0.95 km	1.15 km
Running time up	45 min.	39 min.
down	32 min.	
Schedule speed up	25 km/hr	35 km/hr
down	35 km/hr	
Maximum speed	80 km/hr	80 km/hr

4.7.7 Planned transport capacity

The planned transport capacity with Route 1 and Route 2 changed to monorail from the subway in the previous Table 4-6-1 will be as shown in the following Table 4-7-4.

Table 4-7-4 Planned Maximum Transporting Capacity at Rush Hour

	Route	Total person trip/day Unit: 1000	One sided person tri trip/day Unit: 1000	One sided rush hour traffic/hour by rapid transit Unit: persons	Planned maximum transporting capacity/hour Unit: persons	Riding efficiency %	Cars/train cars	Minimum operating head min: sec.	Operating trains/hour trains
Monorail	1	700	350	35000	19730	178	6	2m 30s	24
"	2	562	281	31000	16440	189	6	3m 00s	20
Subway	3	1261	631	45000	28800	155	8	2m 30s	24
"	4	912	456	33000	21600	149	6	2m 30s	24
Improved state railway	for Karaji	315	157	-	-	-	-	-	-
	for Rey	310	155	-	-	-	-	-	-
	for Qom	81	41	-	-	-	-	-	-
Total		4141	2071	-	-	-	-	-	-

4.7.8 Estimated construction costs of monorail

Estimation of construction costs was made separately for each category such as track construction (civil works including the construction of tunnel, pylon and track beam), station facilities, power facilities, signal and communication facilities, car shed, rolling stock and administration expenses in the manner similar to that employed for the subway.

The result of estimation is shown in Table 4-7-5. The methods employed for the construction of pylon and the fabrication and erection of track beam for the standard section have already been discussed. Construction method for the tunnel for the underground section has also been discussed in the section for the subway project. As the pylon may be erected in the medial divider of the road in the standard section in principle, purchase of land is not considered necessary. Where the road has to be widened because of insufficient width for erection of pylon, where the gate type pylon has to be erected in the privately owned land and where stairways to the station have to be built in the privately owned land, the space required must either be purchased or compensated for. Expenses for such purposes must be appropriated separately from the construction costs shown in Table 4-7-5. The cost of rolling stock was calculated first by obtaining the number of required rolling stock on the following assumption and by adding 15% of the total number as spare cars.

Minimum head in rush hours:

Route 1	8 car formation	2 min. 30 sec.
Route 2	8 car formation	3 min.

The number of rolling stock mentioned here is the number required to meet the estimated transport demand in the target year of 1991 when all the project lines will have been completed for operation. Therefore, the number of rolling stock required for partial operation of the project lines before the target year may be less than the above figure, corresponding to the transport demand at that particular time.

Table 4-7-5 Estimated Construction Costs of Monorail

	Route 1		Route 2	
Track	km 19.0	M. Rial 1594	km 23.1	M. Rial 2192
Station facilities	station 21	450	station 21	520
Power facilities	km 19.0	618	km 23.1	662
Signal and communication facilities	complete 1	312	complete 1	279
Car shed	complete 1	480	complete 1	408
Rolling stock	car 228	1961	car 194	1669
Administration expenses	complete 1	276	complete 1	325
Total		5691		6055
per km cost		300		262