CHAPTER 6

Electrification Program

6-1. Lines Covered by the Electrification Program

The electrification program under consideration covers the parts of the following sections of the existing lines for passengers, the electrification being intended to provide electric cars.

(1) Main Line

Electrification of the section between Karachi City and Pipri. (double-track) (22.9 mile = 36.9 km)

(2) KCR

Electrification of the section between Karachi City and Drigh Colony. (single-track) (18.0 mile = 29.0 km) And of the section between Depot Hill and Drigh Road as a single-track line (1.1 mile = 1.8 km)

(3) Malir Cantt Branch

Electrification of the section between Malir Colony and Malir Cantt. (single-track) (5.2 mile = 7.6 km). Although the information required for the investigation of this branch is still to be provided to us by PR, the branch was selected as a section subjected to electrification under this feasibility study with respect to the demand for passenger traffic and the train operating plan.

(4) Electric-car depots and workshops incidental to the above-mentioned electrification.

Sections required to be newly provided as a result of line additions and elevated bridges should be electrified whenever deemed necessary.

6-2. Selection of Electrification System

The conditions necessary for determining what electrification system should be employed in the sections to be electrified as described in the preceding paragraph will lead to more accurate, economical transportation of high density passengers living in the Karachi Metropolitan Area having a limited area of about 10 miles in radius. Such conditions should also be taken into considerations as the possibility of introducing subways in the future. For these reasons, electrification should be effected by the adoption of electric cars, and electrification of the existing lines will be planned to meet passenger traffic flow.

Based on the above-mentioned literature, a comparative study will be made as to the possibility of adopting alternating current or direct current. It was decided that the former should use 50 Hz 25kV so as to be the same as the existing lines to be electrified, and the latter should use 1,500 volts with which JNR has long experienced in its history and which is stable. Accordingly, either of these two systems should be selected for this Project.

Table 6-1 shows the comparison of 50 Hz single-phase AC 25kV with DC 1,500 volt, with respect to above-ground facilities and overhead facilities.

In general, AC electrification permits substations to be located relatively far from each otehr, hence a smaller number is required and it has advantages over DC electrification. However, the Karachi Metropolitan Area will not allow the above-mentioned advantages to have effect in carrying-out of electrification with respect to distance, and it may not necessarily be said to be advantageous. As shown in Table 6-2, this varies with the concept on how facilities should be laid out. AC electrification requires investment in substation-related facilities about 1.1 to 1.4 times that required by DC electrification. Also, an AC Electric Multiple Unit (E.M.U.) costs about 20% more than a DC E.M.U. Therefore, insofar as the amount of investment is concerned, DC is superior to AC under the condition that it be provided in the Karachi Metropolitan Area. In addition, DC has a long history and is markedly stable with respect to techniques, thus is worthy of a better rating. This report, however, will not ignore the relationship of the expansion plan for the electrification of the main line to the already electrified section between Lahore and Khanewal forming a nucleus. The problem is which should be given priority over the other, the Karachi Metropolitan Area or the entire main line. Should the former be given priority, how to link the two must be clarified. On the premise that such a step be taken when a freight yard is provided in Pipri in the future, it is easy to envisage the selection of Pipri as a junction point of AC and DC systems to be carried out at the time when the main line has been fully electrified.

Table 6-3 shows a plan in which what types of traction unit should be used as per type of electricity considered when Pipri is selected as the junction point of AC and DC systems.

Table 6-1 Comparison between 50Hz Single-Phase AC 25kV and DC 1,500V in the Karachi Metropolitan Area

(PART 1)

	Items for comparison	50 Hz single-phase AC 25kV		DC 1,500V	
Ground facilities	Substation	X	Because of the electrification to be carried out in the city region involving relatively short distance, substations can-not be located remotely so as to provide as few substations as possible.	O	Because of the high den-sity population in the Metropolitan Area, move substations required can be utilized effectively.
	Feeder voltage	O	With transformers used in elec-tric cars, high voltage can be used.	X	Because of restrictions in the insulation of traction motors and DC transforming equipment, high voltages cannot be used.
	Electric-car track	O	Small electric current, not much copper is required and catenary structure can be of light weight.	Δ	Large electric current, much copper is required and the catenary must be capable of withstanding a heavy load.
	Track circuit	X	50 Hz track circuit cannot be used.	O	50Hz track circuit can be used.
	Insulated separation	X	High voltage, insulated separa-tion is large.	O	Low voltage, insulated separation is small.
	Voltage drop	O	Series capacitors can perform compensation easily.	Δ	Addition of feeder lines and provision of sectioning posts of substations are required.

	Items for comparison		50 Hz single-phase AC 25kV		DC 1,500V
Ground facilities	Protection	O	Small traction current, easy to determine fault current and simple to provide protective devices	Δ	Large traction current and difficult to select and break fault current, separate protective devices must be provided.
	Inductive interference to telecommunication line	X	Large inductive interference and depending on the extent of interference (details unknown because data is not yet available), the cost for countermeasures such as provision of cabling, etc. great. In addition, provision of negative feeders and booster transformers is required.	O	Small degree of inductive inter-ference, subvision of filters in substations. Special devices in contact line is not required.
	Unbalance	Δ	Because single-phase load causes ubbalance in 3-phase power sources, countermeasures must be provided.	O	Nothing to cause problem of unbalance in 3-phase power source.
Equipment on rolling stock	Pantagraph	O	Small and light current pantagraph traceability is superior.	Δ	Large current, thus heavy pantagraph, traceavility is inferior than in AC system.
	Protection	O	Easy to break AC small current, select and break fault current as compared with breaking of large DC current, thus protection can be provided in a simpler way.	Δ	Difficult ot break large DC current, select and break fault current, provision of protection is difficult.

	Items for comparison		50 Hz single-phase AC 25kV		DC 1,500V
Iquipment and rolling stock	Speed control	O	Speed control can be performed easily by switching the tap of transformer.	Δ	In general, speed control is complicated.
	Adhesion performance (traction force)	O	Superior adhesion performance, larger load can be pulled by small capacity motive power units.	Δ	Inferior adhesion performance, larger output is required compared with AC motive power units.
	Auxiliary equipment	O	Using a transformer, AC power source of arbitrary low voltage can be applied and a simple, durable induction motor can be used.	Δ	Driving the DC unit by means of contact wire voltage, more complex structures are required.

Legend

O ------- Advantageous

Δ ------- Rather disadvantageous

X ------- Disadvantageous

Table 6-2 Comparison between 50 Hz Single-Phase AC 25kV and DC 1,500V in the Karachi Metropolitan Area

(PART 2)

Items for comparison		50Hz single-phase AC 25kV		DC 1,500V
Relation with existing electrification system	O	Same as that existing in the section between Lahore and Khanewal, this is more advantageous in view of future electrification of the main line.	Δ	In consideration of future electrification of the main line, both systems must be used. The Pipri yard is the best connecting point.
High density traffic in the Karachi Metropolitan Area	Δ	Not as much experience as DC 1,500V	O	Many years of experience technically simple.
Relation with subway (R/T Spine)	Δ	As larger insulated separation is required, the construction cost will be much higher. In addition there is little experience of this in the world.	O	As above.
Cost for the provision of substations and incidental works	Δ	1.2 - 1.3 times the cost of DC 1,500V	O	1 (the cost of DC 1,500 is taken as 1.)
Price of vehicles to be procured	Δ	Price of vehicles approximately 1.2 times by DC 1,500V	O	As above

Table 6-3 Comparison between Motive power units by Electrification system

Types of train / Electrification system / Section to be electrified		Karachi-City∿Pipri		Karachi-City∿Lahore	
		AC 25kV	DC 1,500V	AC 25kV	DC 1,500V
Passenger train	°Local				
	Karachi City - Pipri	EC (AC)	EC (DC)	-	-
	KCR	EC (AC)	EC (DC)	-	-
	R/T Spine (future)	EL (AC)	EC (DC)	-	-
	°Medium-distance				
	Karachi City - Kotri etc.	DL	DL	EL (AC)	EL(Dual current AC and DC or change EL)
	°Long-distance				
	Karachi City - Rawelpindi etc.	DL	DL	EC (AC)	EL(")
	High-class train	DL	DL	EL (AC)	EL(")
Freight train	°Local				
	Reception Yard - Pipri-Yard	EC (AC)	EL (DC)	-	-
	°Long-distance	-	-	EL (AC)	EL(")

Summarizing the above-mentioned points, the following propositions are presented in this feasibility study for the employment of DC electrification (including electric cars) in the Karachi Metropolitan Area.

(1) Electrification is to be carried out in a limited area (about 10 miles in radius) of the Karachi Metropolitan Area.

(2) Provision of mass rapid transport system should be effected to deal with carrying high density passengers. Freight transport is not subject to this feasibility study.

(3) The possibility for the introduction of subways (including R/T spine) should be taken into consideration.

6-3. Preconditions for the Electrification Program

The following train compositions and headways in rush hours constitute the preconditions for the design of electric traction facilities and are as shown in Table 6-4, which refer to CHAPTER 4: Plan for Train Operation and Rolling Stock.

Trains in both Phases consist of 6 electric cars with composition of 4M2T. In this case, the basic unit of train composition is 2M1T. In view of the demand forecast of transportation, the time when the number of cars in a train should be increased will be in 1992, and trains should consist of 9 electric cars (6M3T) from that time. Also, the head way at rush hours in 2002 may be judged to be 6 minutes which will be sufficient to handle the passengers.

Based on these preconditions, the present electrification plan should be promoted in such a manner that any large backlog of work should not occur in the future. Also, with regard to facilities which can be provided additionally in the future without any large backlog of work, they should be arranged as to cope with train operations for the time being, namely, for substations and electric-cars depot, first land should be acquired, then facilities and systems should be provided.

Table 6-4 Train Operation Plan

Line	Section	Phase 1 (1982)			Phase 2 (1987)		
		No. of electric car in a train	Headway in rush hours	Traffic capacity per rush hour	No. of passenger car in a train	Head way in rush hours	Traffic capacity per rush hour
Main Line	Karachi City - Landhi	6	minutes 10	* 300 x 6 x 6 = 10,800 passengers	6	minutes 7.5	* 300 x 6 x 8 = 14,400 passengers
	Landhi - Pipri	6	20	300 x 6 x 3 = 5,400 passengers	6	15	300 x 6 x 4 = 7,200 passengers
KCR	Drigh Road - Karachi City	6	15	300 x 6 x 4 = 7,200 passengers	6	10	300 x 6 x 6 = 10,800 passengers
	Drigh Colony - Depot Hill	6	15-30	225 x 6 x 3 = 4,050 passengers	6	15	225 x 6 x 4 = 5,400 passengers
Malir Cantt Branch	Malir Colony - Malir Cantt	6	20	225 x 6 x 3 = 4,050 passengers	6	16	225 x 6 x 4 = 5,400 passengers

Notes: (1) 6-electric-car 4M2T

(2) In Phase 2, operation of rapid service trains on the main line for the section between Karachi City and Drigh Road is envisaged.

* = Passenger x No. of electric car x No. of trains

6-4. Location of Traction Substations and Connecting Transmission Lines

6-4-1 Locations of substations

The substation should generally be located at the center of the load. It is necessary, however, to take into consideration leading-in of incoming lines, leading-out of feeders, soil bearing power, transportation of instrument conditions of location and so on to actually determine the location of a substation. In our plan, the intervals between traction substations were first determined so so as to be most economical by taking into account the voltage drop of feeders and current breaking facilities at the time of faults. Then, taking into account the locations of power stations and substations of the K.E.S.C. power supply system diagram, seven traction substation locations, corresponding to the load conditions under Phase 2, and the location of a control center which engages in supervisory remote control over the traction substations were determined. We propose to place the control center in or near the yard of Karachi Cantt station where the regional office and train operation center are situated.

The locations of traction substations are shown in Fig. 6-4-1.

6-4-2 Power source receiving

A transmission line network of 132 kV is provided along the outside of the main and K.C.R. lines for which an electrification project has been set up and the buildup of the transmission line network is now under way.

On the basis of the K.E.S.C. power supply system diagram (see Apendices B to G), we have made a power source receiving plan of seven traction substations. The locations of traction substations are shown in Fig. 6-4-2.

The power source receiving plan should be examined by K.E.S.C. for the possibility of power supply in relation to the capacities of the grid station and to the future program.

This plan does not cover facilities for the transmission line from the K.E.S.C. grid station to the traction grid station which we

Fig. 6-4-1 Layout of Grid Stations

(Electrification Plan of KARACHI Suburban Area)

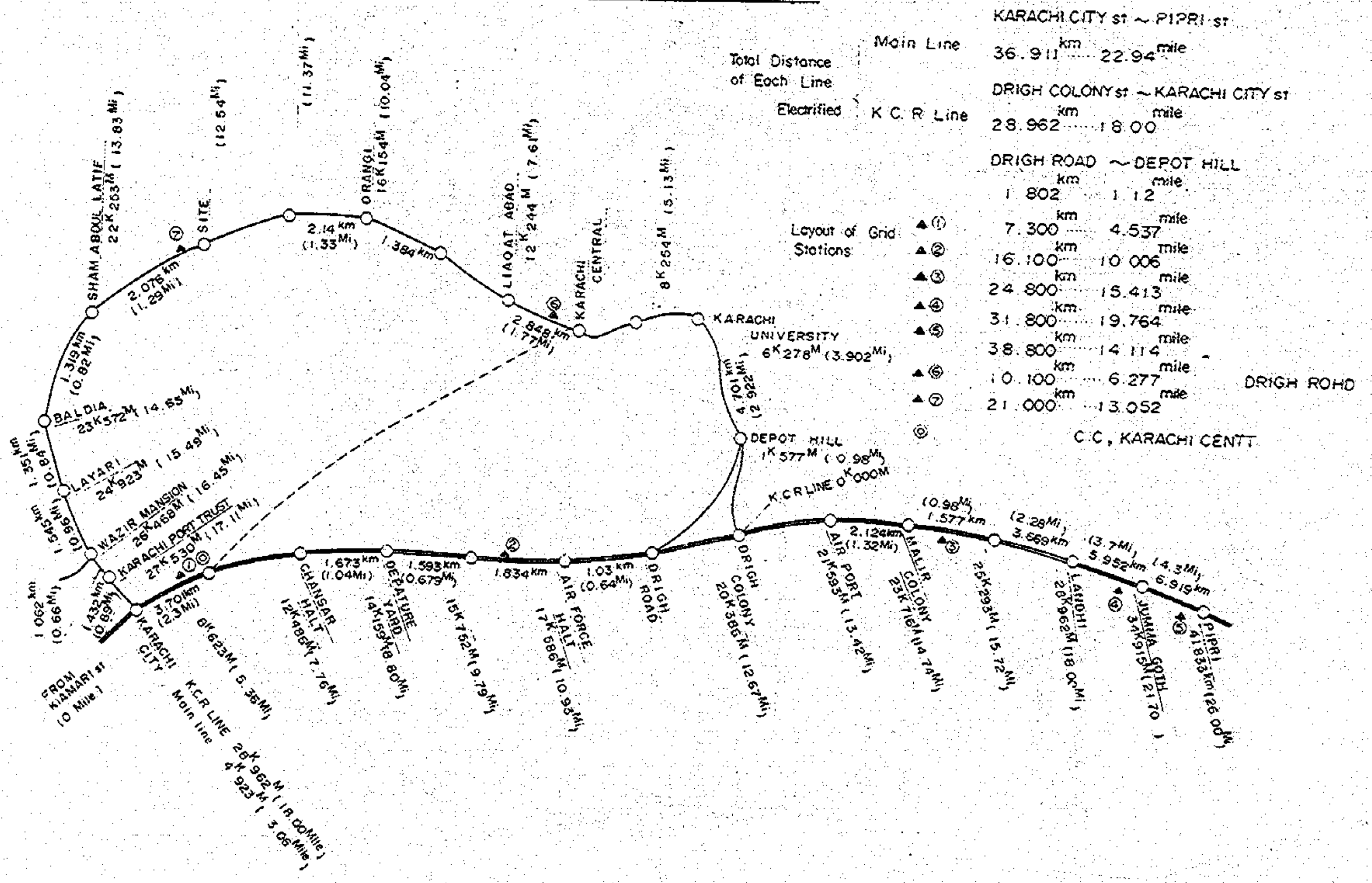
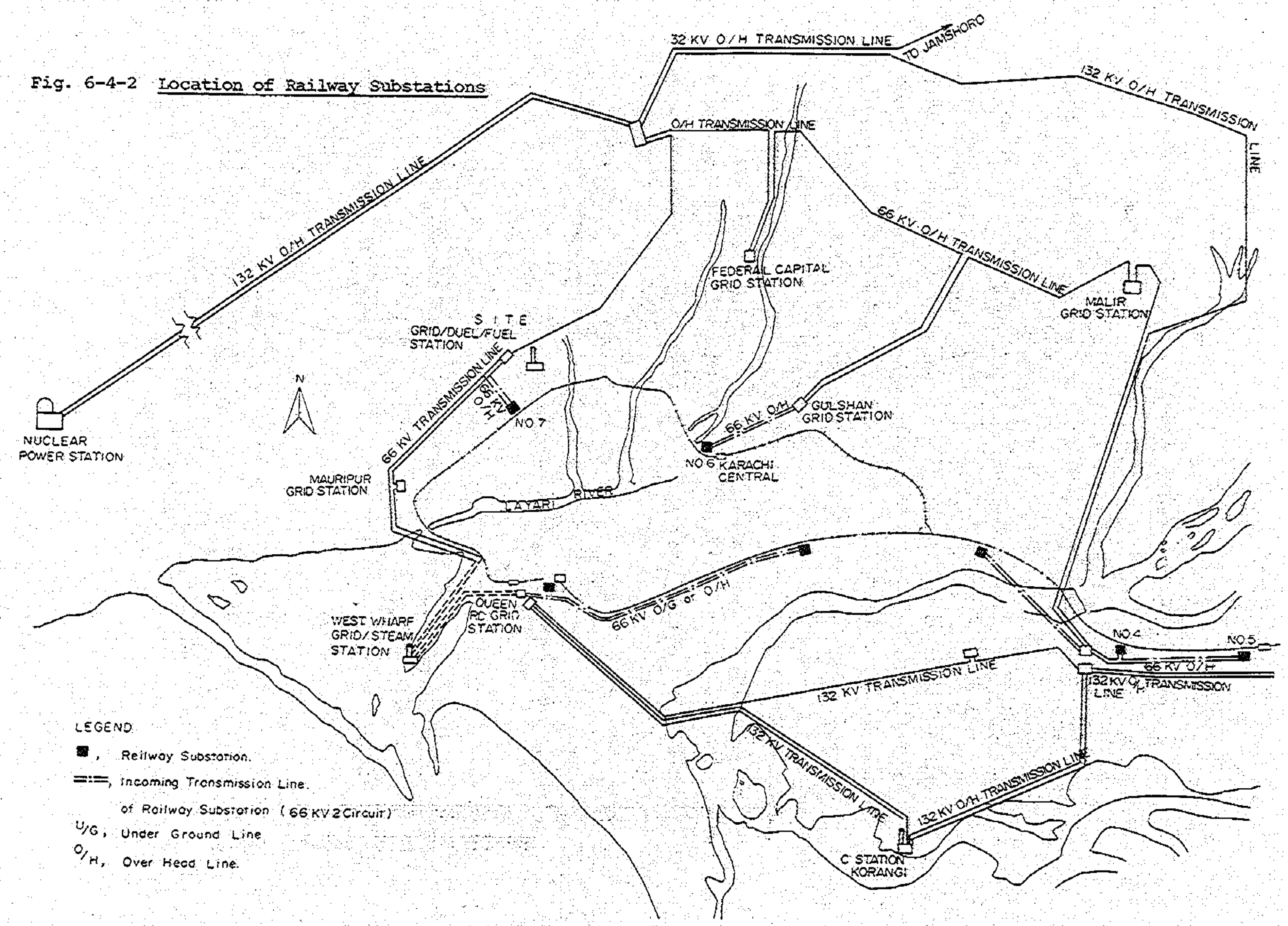


Fig. 6-4-2 Location of Railway Substations



consider should be planned by P.R.

6-4-3. Connecting transmission lines

(1) No.1 traction substation

We assume that this substation should receive power through a two-circuit 66 kV underground cable from the K.E.S.C. Elander Road grid station.

(2) No.2 traction substation

We assume that this traction substation should receive power through a two-circuit 66 kV underground cable or overhead transmission line from the K.E.S.C. Queen's Road grid station.

We consider the Elander Road grid station can supply power not only to No. 1 substation but to No. 2 substation if its transmission capacity is large enough or its area is large enough to install additional transmission equipment.

(3) No.3 traction substation

We assume that this traction substation should receive power through a two-circuit 66 kV overhead transmission line from the K.E.S.C. Landhi grid station.

According to Appendices B, C, G and E, the Landhi Station transmission facilities are planned to raise the voltage from 66 kV to 132 kV. But we assume K.E.S.C. should leave the Landhi Station's 66 kV transmission facilities so that they can be used for the traction substation.

(4) No.4 and No.5 traction substations

We assume that No. 5 traction substation should receive power through a two-circuit 66 kV overhead transmission line from the K.E.S.C. Landhi Station while No.4 substation should receive power from a two-circuit 66 kV transmission line branching from the middle of the line for No.5 traction substation

(5) No.6 traction substation

We assume that this traction substation should receive power through a two-circuit 66 kV overhead transmission line from the

K.E.S.C. Gulshan grid station.

(6) No.7 traction substation

We assume that this traction substation should receive power through a two-circuit branch line from the 66 kV overhead transmission line which connects the K.E.S.C. West Wharf Station with the S.I.T.E. Station.

6-4-4 Voltages of incoming power

The electrification project aims at operation of the railway by 1500 V direct current. The construction cost will be low if the voltage of incoming power is selected to be as low as possible, taking into account transformers, within the permissible limit of the transmission capacity.

Considering the power consumption and electric charges, however, a high voltage may be favorable in the long run. Here we have studied measures to reduce the initial cost of construction. From the K.E.S.C. transmission system diagram, we consider either of 132, 66 and 11 kV lines are possible for the incoming voltage to traction substations. The 11 kV lines seem to have the problem of transmission capacity while the construction cost of voltage step-down equipment is high for the 132 kV lines. The 66 kV lines are most desirable, considering the cost and performance of substation facilities and the reliability of the power source for electrified operation. However, the possibility of receiving power at 11 kV should be investigated for No.3, No.4 and No.5 substations considering the transmission capacity since the voltage of the existing facilities is planned to be stepped up from 66 kV to 132 kV.

6-5. Feeding System and Voltage Drop

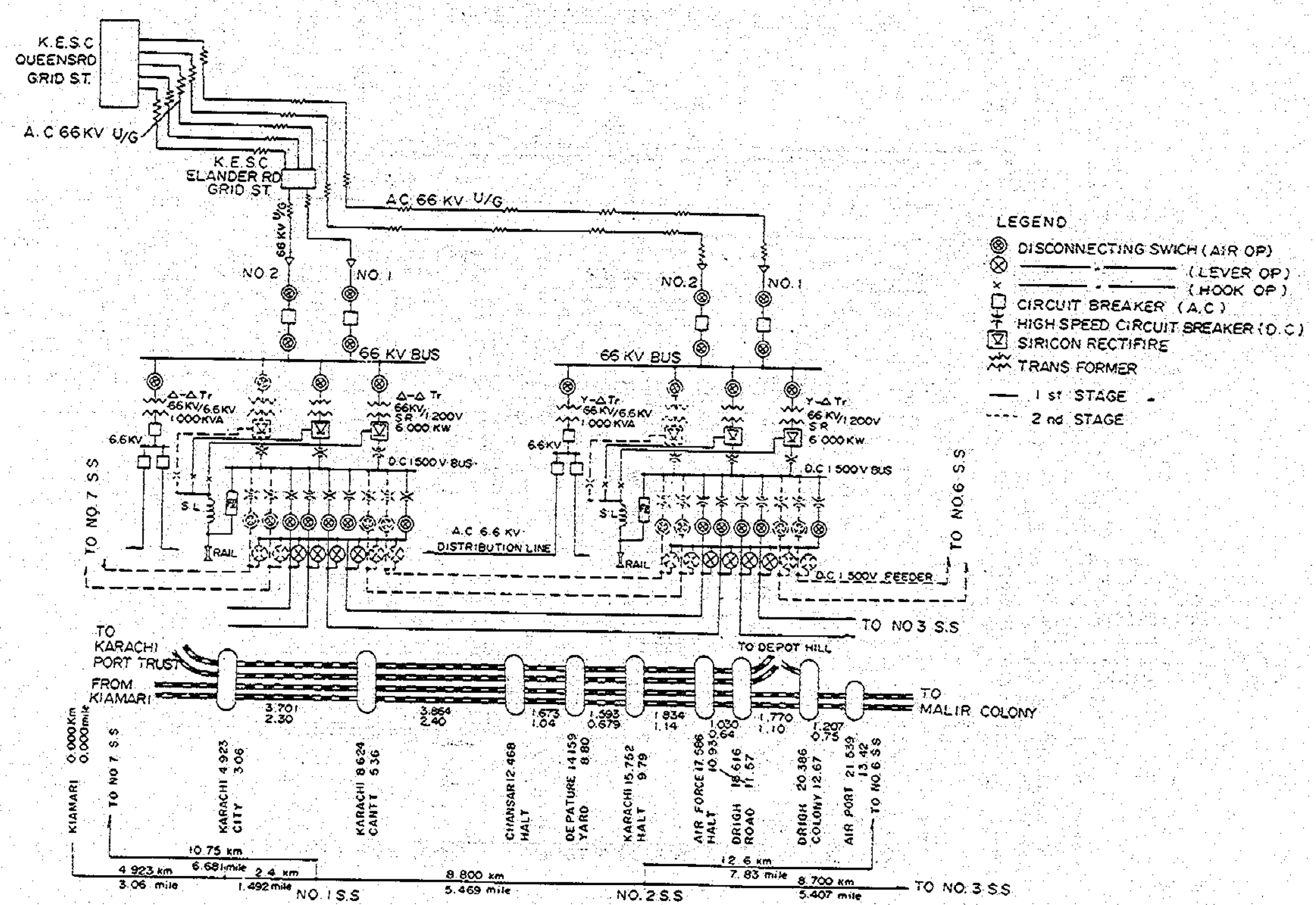
6-5-1 Feeding system

The bussbar of a traction substation feeds 1,500 V DC power to each section and each track. The parallel feeding system of adjacent substations is adopted to reduce voltage drop.

Fig. 6-4-3 shows the power supply transmission system diagram

MAIN LINE

Fig.6-4-3(1) Power Supply Transmission System Diaglam (1)



KCR LINE

Fig. 6-4-3 (2) Power Supply Transmission System Diagram

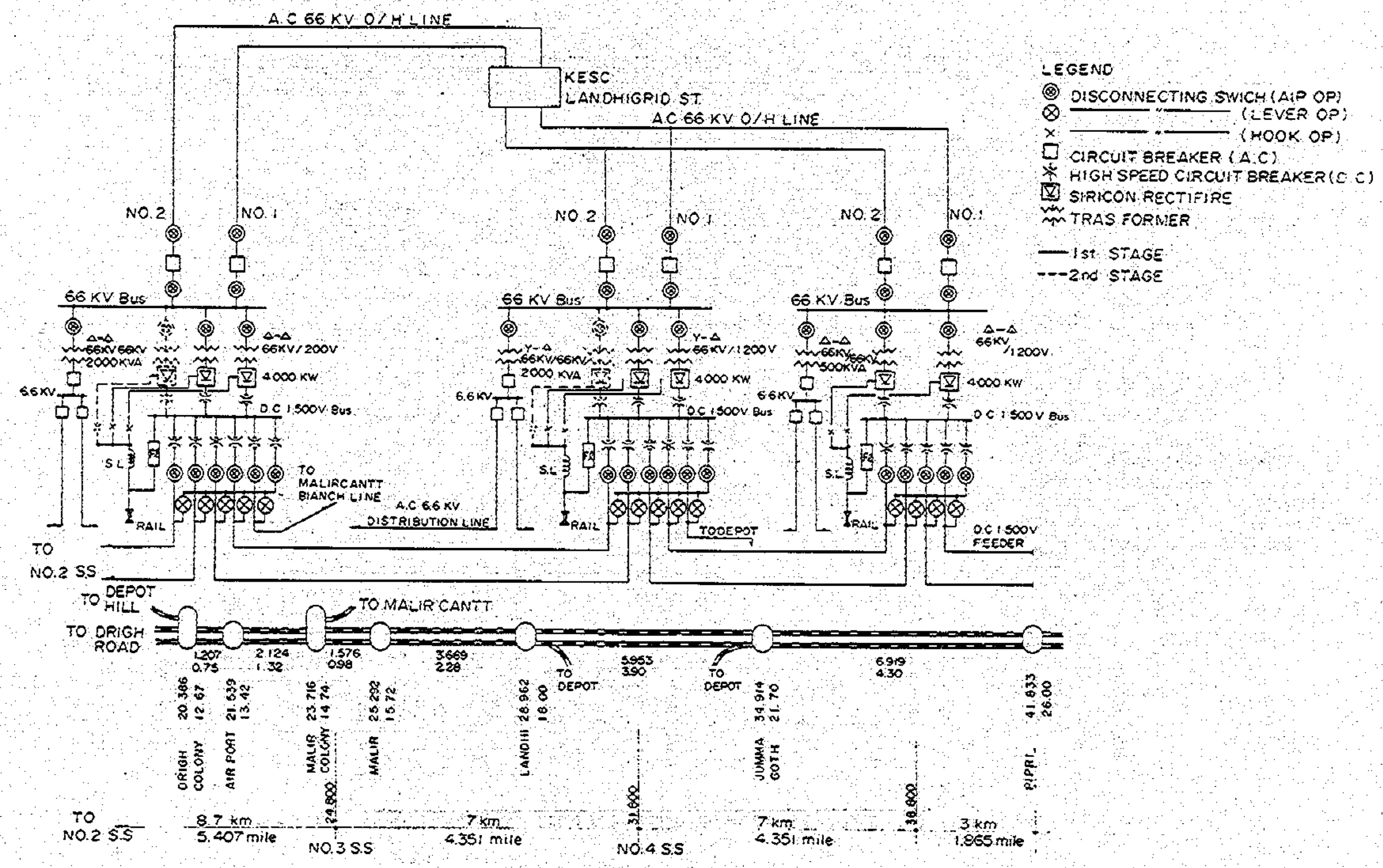
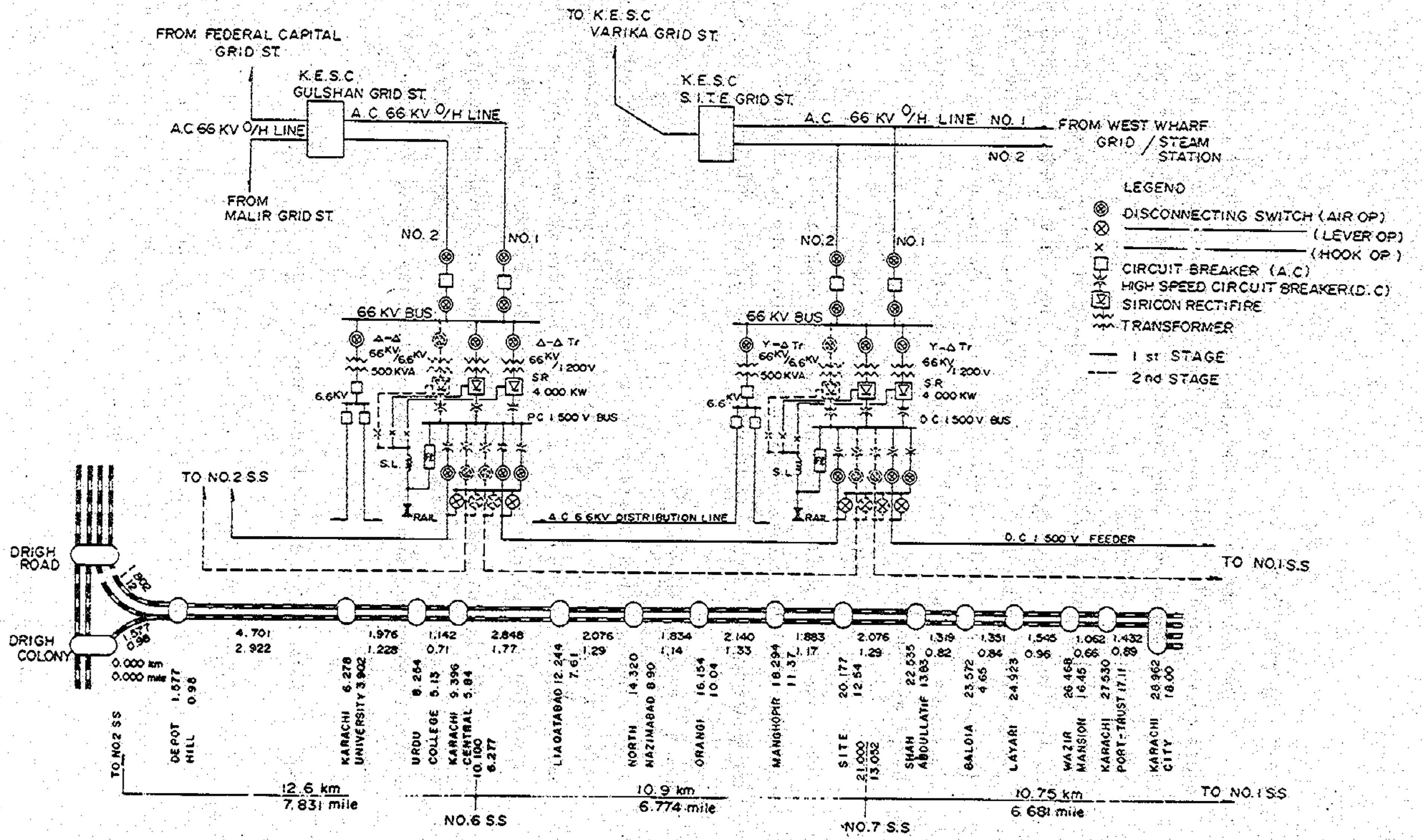


Fig. 6-4-3 (3) Power Supply Transmission System Diagram (2)



6-5-2 Voltage drop

The voltage drop is determined by the number of trains being operated in a feeding section, load currents of the trains and the feeding circuit constants. The voltage drop becomes larger as the feeder distance becomes longer.

In our plan, the permissible limit of voltage drop is 600 V assuming the overhead contact line voltage to be 900 V. When calculating the voltage drop, we assumed operating conditions such that maximum load is situated in the middle of two substations and power running loads are located at both sides of the maximum load with operating intervals before they start running.

Fig. 6-4-4 shows the voltage drop curves.

We have planned the intervals between traction substations so that not only the voltage drop is held within the permissible limit but the fault current break of feeders can be cut off reliably.

6-5-3 Extended feeding

The traction substations are interconnected to each other by the parallel feeding system. We propose a system whereby when one traction substation is suspended during a power failure or servicing, an adjacent substation will supply power to the section by extended feeding.

We have planned the load conditions of extended feeding so that the minimum feeding voltage and fault current breaking facility can be satisfied when maximum load is assumed at the middle point between the two substations.

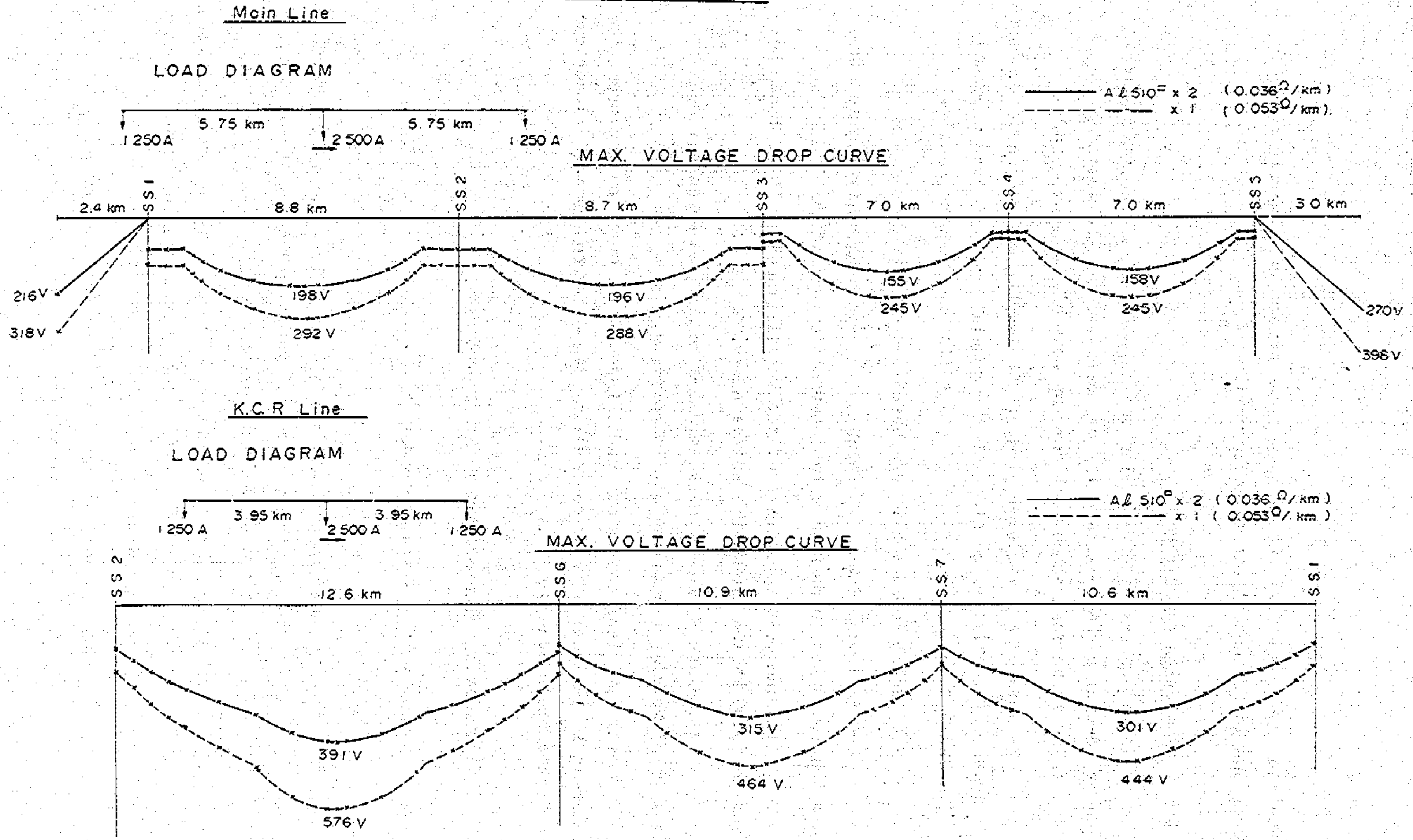
6.6. Traction loads and substation capacities

6-6-1 Traction loads

The load of a traction substation is an aggregate of electric cars which repeat a sequence of operations; starting, power running, coasting, and slowing down to stop. These are concentrated loads rapidly changing in a short time.

The ratings of traction substation equipment are therefore

Fig. 6-4-4 Voltage Drop Curve



required to be such that the equipment can handle such rapidly changing loads and instantaneous overloads as well.

6-6-2 Substation capacities

It is necessary to determine the capacity of a traction substation by combining the unit capacity of rectifier and the number of rectifiers so as to be most economical for any possible maximum load.

We have made a rational plan of the rectifier's unit capacity and the number of rectifiers considering the possible maximum load expected in the Phase 2 so that extension of substation can be made easily.

Tab. 6-4-1 shows a list of substation capacities.

The following items are those which have been particularly taken into consideration to determine the substation capacities.

(1) The unit capacities of the rectifiers under Phase 1 are unified to 6,000 kW and 4,000 kW considering Phase 2.

(2) A set of spare rectifiers are considered necessary upon failure of working rectifiers and for service.

(3) The load conditions under Phase 2 are based on the operation schedule in the year of 2002 considering temporary concentrated loads due to broken train schedule.

6-7. Substation Equipment and Protective Relaying System

6-7-1 Traction substation equipment

(1) System

a. A dual power receiving system is used for traction substations to prevent the system from being interrupted by a failure of the working system or during servicing.

b. Extended feeding is provided to secure minimum operation of trains if a substation stops supplying power due to a power failure or a fault in the transmission system.

c. The seven traction substations are operated unattended under remote control from the control center at Karachi Cantt.

Table 6-4-1 Capacities of Traction Substation Equipment

Equipment	Stage	SS NO1	SS NO2	SS NO3	SS NO4	SS NO5	SS NO6	SS NO 7	Remarks
Rectifiers	1st Initial equipment	6,000 x 1 + 1 (spare) 12,000	6,000 x 1 + 1 (spare) 12,000	4,000 x 1 + 1 (spare) 8,000	4,000 x 1 + 1 (spare) 8,000	4,000 x 1 + 1 (spare) 8,000	4,000 x 1 +1 (spare) 8,000	4,000 x 1 + 1 (spare) 8,000	
	2nd Additional equipment	6,000 x 1 6,000	6,000 x 1 6,000	4,000 x 1 4,000	4,000 x 1 4,000	-	4,000 x 1 4,000	4,000 x 1 4,000	
	Total	6,000 x 2 + 1 (spare) 18,000	6,000 x 2 + 1 (spare) 18,000	4,000 x 2 + 1 (spare) 12,000	4,000 x 2 + 1 (spare) 12,000	4,000 x 1 + 1 (spare) 8,000	4,000 x 2 + 1 (spare) 12,000	4,000 x 2 + 1 (spare) 12,000	
High volage distribution system	1st	1,000 x 1 1,000	1,000 x 1 1,000	2,000 x 1 2,000	2000 x 1 2,000	500 x 1 500	500 x 1 500	500 x 1 500	
	2nd	-	-	-	-	-	-	-	
	Total	1,000 x 1 1,000	1,000 x 1 1,000	2,000 x 1 2,000	2,000 x 1 2,000	500 x 1 500	500 x 1 500	500 x 1 500	

(2) Types of traction substations

In the two types of traction substations, indoor and outdoor, the latter is generally less expensive to construct. But the indoor type may be favorable if it is difficult to obtain enough area. In this plan, No.1 substation which is to be installed in an urban area is of the indoor type while other traction substation are to be build outdoors. The locations and types of traction substations should be reinvestigated when they are to be designed so as to meet the actual condition of site.

(3) Configuration

a. Incoming system

Two circuits are used to receive power with an incoming circuit breaker provided for each circuit.

b. Converter system

A converter and a rectifier make a pair. Extension is possible in units of pairs under Phase 2.

c. High voltage distribution system

A set of high voltage distribution converters is installed in each traction substation.

The capacity of high voltage distribution converter corresponds to the loads under Phase 2 and is determined to have a marginal capacity for the rise in ambient temperature.

d. Feeding system

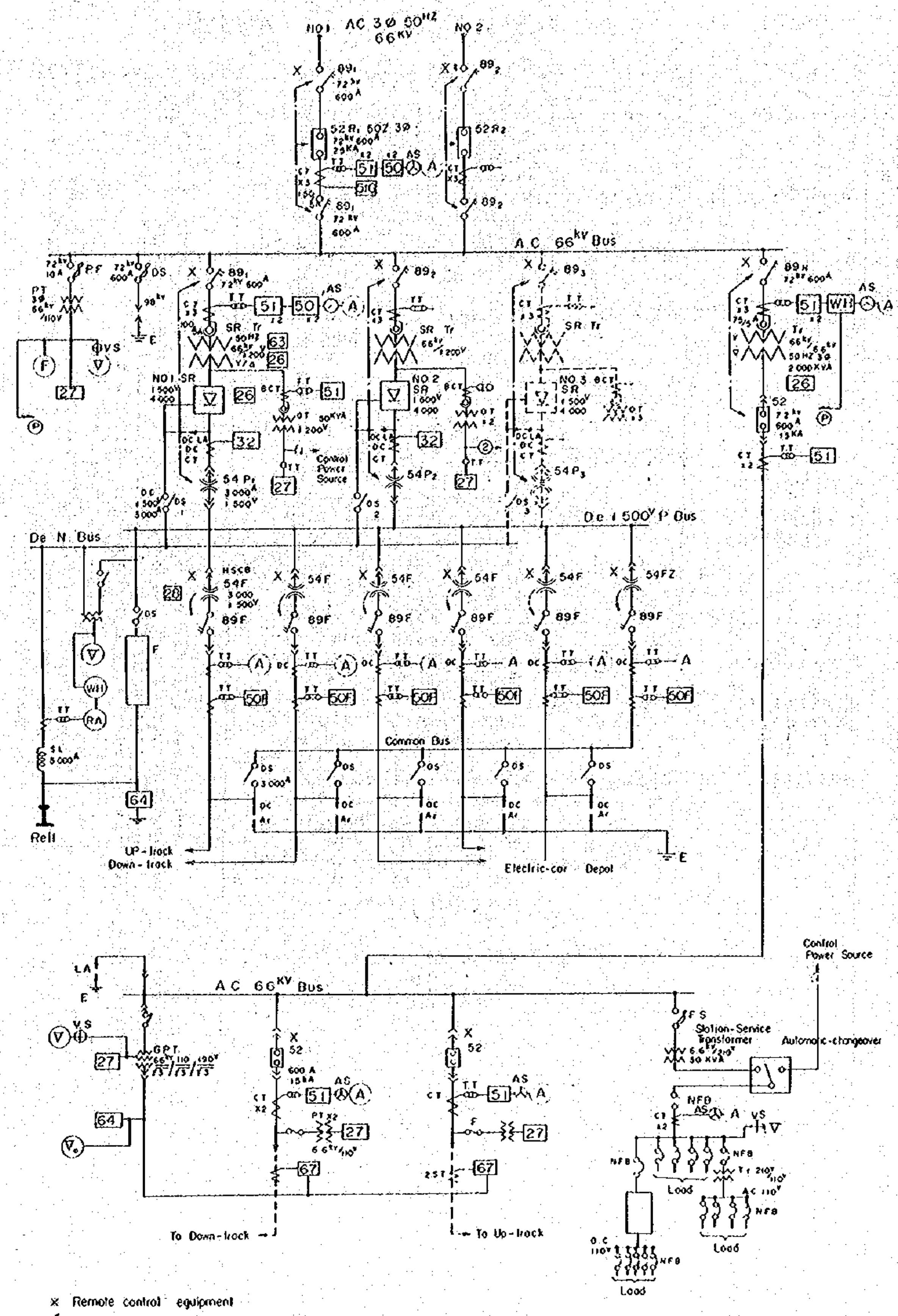
A DC high speed circuit breaker is provided for each section and each track and power is fed from a common DC bus.

Fig. 6-4-5 shows the skeleton diagram of No.4 substation as an example.

6-7-2 <u>Protective relaying system</u>

A standard traction substation protective relaying system is shown in Tab. 6-4-2.

Fig. 6-4-5 Electrification of KARACHI Suburbon Area
Single-Wiring Diagram of Grid Station
(Example: No. 4 Grid Station)



× Remote control equipment

(Electrically interlocked equipment

— Phase 1

--- Phase 2

Table 6-4-2 Protective relaying system of substation

System	Trouble	Operating relay (including DC high speed circuit breaker)	Circuit breakers to be opened
Incoming system (from transmission line to the inlet of extra-high tension bus)	Overload	Overcurrent relay (51).. operated with continuous current exceeding a certain level.	Incoming circuit breaker
	Short-circuit	Short-circuit relay (50)..operated at high speed when an overcurrent occurs.	
	Grounding	Grounding relay (51G)..operated by a grounding current.	
Converter system (from the disconnector at the primary side of transformer to the bus at the output side of rectifier)	Transformer trouble	Pressure relay (63)..operated by pressure rise due to trouble inside transformer.	Incoming circuit breaker and high speed circuit breaker at the rectifier's DC side.
	Short-circuit	Short-circuit relay (50)..operated rapidly by an overcurrent in transformer	
	Transformer overload	Overcurrent relay (51)..operated with continuous current exceeding a certain level	
	Transformer overheating	Temperature relay (26)..operated by detecting the rise of transformer oil temperature to above a predetermined value.	High speed circuit breaker at the rectifier's DC side and disconnector at the transformer's primary side
	Reverse current in rectifier	DC reverse current relay (-2)..operated by continuous reverse current exceeding a certain level.	
	Rectifier overheating	Temperature relay (26)..operated by detecting the rise of rectifier temperature exceeding a certain value.	
	Grounding	Grounding relay (64)..operated by detecting the voltage change berween positive DC bus and ground.	
	Overload	DC high speed circuit breaker (54P).. operated by continuous current exceeding a certain level.	Individually
Others	Power failure	Low-voltage relay (27).. operated when power failure occurs.	Incoming circuit and transformer's secondary side circuit breakers

System	Trouble	Operating relay (including DC high speed circuit breaker)	Circuit breakers to be opened
Feeding system (from feeder bus to track)	Feeder trouble	DC high speed circuit breaker (54F) ..operated instantaneously by a current exceeding a given level. Selective relay (50)..detects a acute current increase (ΔI) in case of trouble	High speed feeding circuit breaker
	Feeder trouble	Interlinked breaking device This ensures recovery from a fault by giving an order to open the high speed circuit breakers of the circuit where the fault has occurred and the associated circuit of substation.	High speed feeding circuit breaker and that of the associated substation
Signal high voltage converter system (from the converter's primary side disconnector to high voltage bus)	Transformer trouble	Pressure relay (63)..operated by the pressure rise due to troubles inside transformer.	Incoming circuit and transformer's secondary side circuit breakers
	Transformer overload	Overcurrent relay (51)..operated by continuous current exceeding a certain level.	
	Transformer overheating	Temperature relay (26)..operated by detecting transformer oil temperature rising over a certain value.	
Distribution system (from high tension bus to catenary)	Overload	Overcurrent relay (51)..operated by continuous current exceeding a certain level.	Signal high tension distribution circuit breaker
	Grounding	AC grounding relay (67)..operated by continuous current exceeding a certain level.	
Common	Control power failure	Overcurrent relay (51)..operated by detecting an overcurrent accompanying short-circuit of control power	Inform the control center of the trouble.
	DC control power failure (remote control power included)	DC voltage relay (80)..operated when DC voltage drops below a certain value.	
	Drop in air pressure	Air pressure relay (63)..operated when the pressure of compressed air, stored in tank to drive circuit breakers and disconnectors, drops below a certain level.	1st action: inform the control center of the trouble. 2nd action: open or lock the related circuit breakers

For the protection of the DC feeding system, AI type fault selective devices and interlinked breaking devices, which have satisfactory records of use in Japan, are installed to make selection of fault currents and protection of feeders certain.

6-8. Construction Sphere of Overhead Contact Line and Obstacles

6-8-1 Construction locations

Contact lines are installed on the main and passing tracks. But on the side tracks of each station, they should be installed to the minimum extent required for the operation of electric cars.

6-8-2 Obstacles

Electrifying the existing lines, such obstacles as level crossings, road overbridges, bridges, tunnels and platform sheds should be taken into consideration.

It is necessary to determine the height of the contact wire at a level crossing by considering the height of automobiles and trucks.

For contact lines in the vicinity of existing overbridges and platform sheds, construction should be determined after investigating the structure including the height and width at each location.

Bridges should be dealt with in the same way to determine the structure of contact lines. The construction of a bridge, plate girder, truss, etc., should be investigated in advance.

6-9. Structure of Contact Lines

6-9-1 Outline of the plan

The contact line transmits power from traction substations and feeds it to the pantograph collectors of electric cars. It is therefore necessary that the contact wire on which pantograph collectors slide should allow smooth sliding of collectors and be resistant to wear. Poles, beams and wires should be free from vibration fatigue and loosening since they are subjected not only to the climate but to vibrations of trains.

The centrifugally compacted reinforced concrete poles are best among various types of poles since they are free from corrosion unlike steel poles and maintenance is easy. Since the raw materials for concrete are available in Pakistan, a concrete pole plant, if constructed, will not only make better use of natural resources in the country but also help produce concrete piles.

As to the catenary, several types such as the simple catenary, compound catenary and double catenary have been put into practical use. Train speed and pantograph current depend the method of installing overhead line. Since the maximum speed of the Karachi Suburban Railway Planned is 110 km/h, we consider the heavy simple catenary is most suitable. The construction is simple and maintenance requires least labor. It makes the current collection performance of pantagraph collector excellent and the wear of contact wire is small. It has a good record of performance for J N R.

The standard height of the contact wire is 5,200 mm while its minimum height is 4,800 mm. The contact wire is provided with a normal zig-zag deviation of 200 mm to prevent grooved abrasion of the slider of the pantograph collector. The gradient of the contact wire against the rails of the main line should be 3 per mill or less to prevent the pantograph collector from coming out of contact with the contact wire when operating at high speed.

Considering possible damage by salt and dust, the contact line of main line is held by hinged cantilever which have stain-resistant insulator stems. On side tracks, a series of two insulators of 180 mm each suspends the contact line.

6-9-2 Design conditions

Loading conditions

The conditions to calculate the strength of insulator, loosening and tension of wires are given below.

Range of temperature change: +50° - 0°C
Standard temperature : +25°C
(Temperature range: standard temperature ±25°C)
Wind velocity : maximum 30 m/s

6-9-3 Standard construction

We use the single-trolley heavy simple catenary with a scheduled maximum speed of 110 km/h.

Hinged cantilever suspend the trolley wire of the main tracks between stations and in station yards. The catenary of side tracks in stations is simply held by brackets.

The standard construction of trolley lines is shown in Figs. 6-9-1, 6-9-2.

1. Suspension

(1) Pole

Concrete poles (centrifugally compacted reinforced concrete poles) are normally used.

Steel poles are used on bridges, in retaining walls and in the yards of big stations.

The construction gauge of a pole is normally 3,000 mm from the track center to the inside of the pole except in station yards.

(2) Foundation of poles

This should be normally made of concrete. But investigation of each construction site will be necessary to finally determine the form of each foundation.

(3) Cantilever

The cantilever is of the hinged type between stations, but hinged and fixed cantilever and used together in station yards where there are many tracks.

The standard spans are shown in Table 6-9-3-1

Table 6-9-3-1 Standard Spans

Radius of curvature (m)	Span (m)
Straight track and 1,600 m or more	60
Over and including 1,000 m to 1,600 m	50

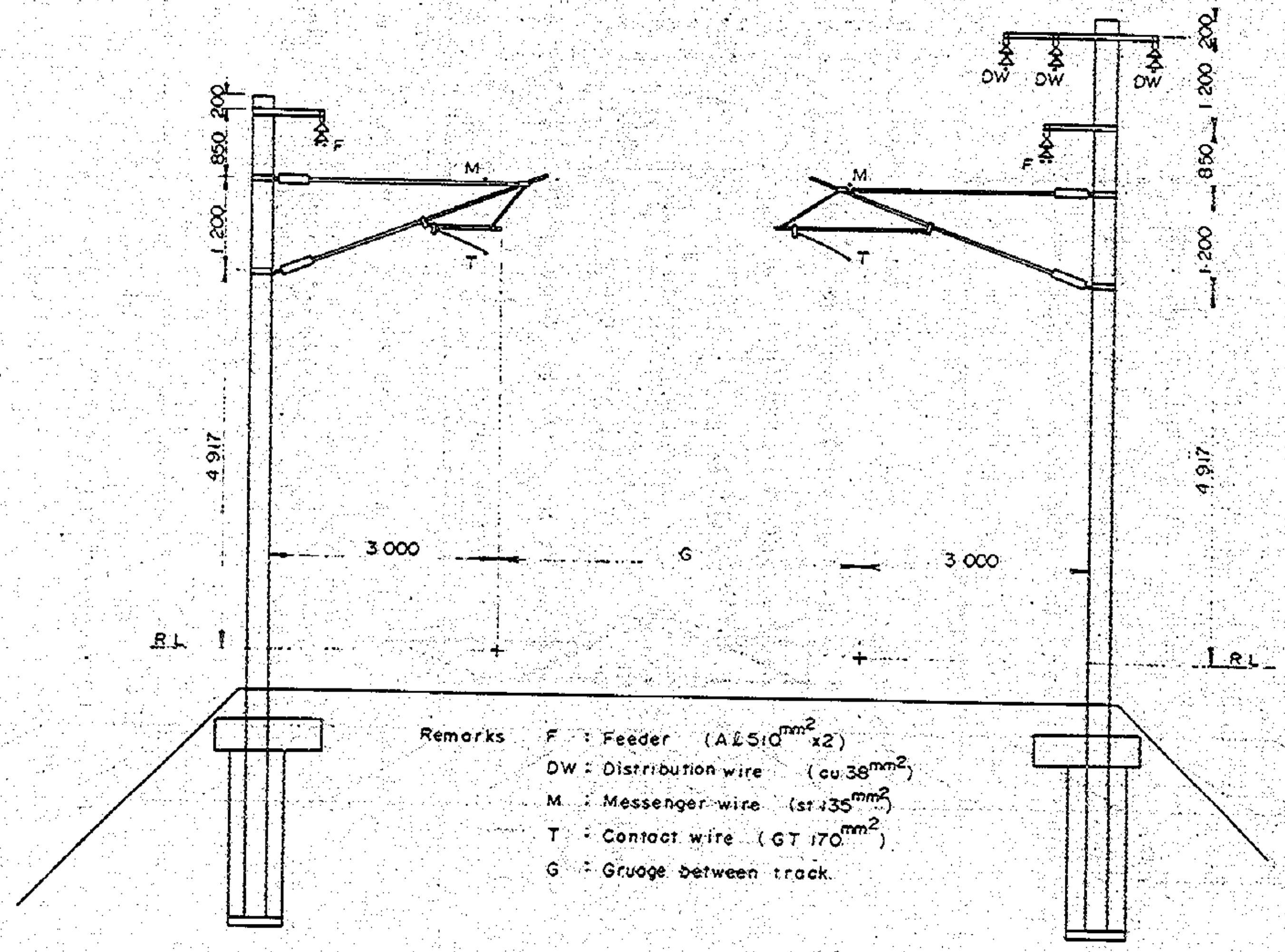
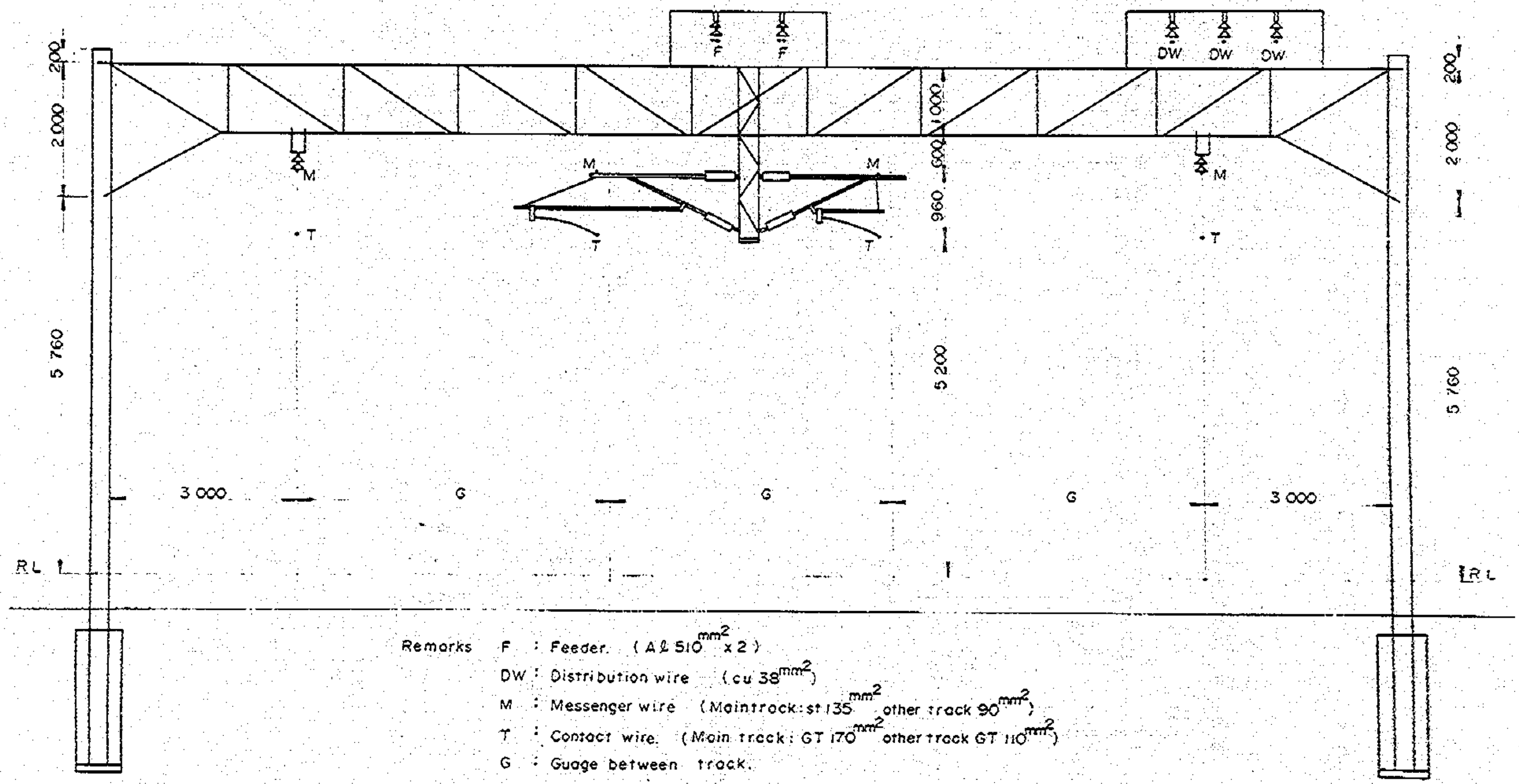


Fig. 6-9-1 Standard Structure of Catenary Line (between Stations)



Remarks
- F : Feeder. (Aℓ 510 mm^2 x 2)
- DW : Distribution wire (cu 38 mm^2)
- M : Messenger wire (Maintrack: st 135 mm^2, other track 90 mm^2)
- T : Contact wire. (Main track: GT 170 mm^2 other track GT 110 mm^2)
- G : Guage between track.

Fig. 6-9-2 Standard Structure of Catenary Line (in Station)

Table 6-9-3-1 Standard Spans (Cont'd)

Radius of curvature (m)	Span (m)
Over and including 700 m to 1,000 m	45
Over and including 500 m to 700 m	40
Over and including 400 m to 500 m	35
Over and including 300 m to 400 m	30
Over and including 200 m to 300 m	20

2. Contact line

(1) Catenary type: simple catenary

Standard tension: catenary cable 1.8T

contact wire 1 T

Heavy simple catenary

(2) Wire types

Wire types are given in Table 6-9-3-2.

Table 6-9-3-2 Wire types

Tracks / Lines	Main track		Side track	
Catenary	Galvanized steel strand wire	135 mm^2	Galvanized steel strand wire	90 mm^2
Contract wire	Grooved hard copper wire	170 mm^2	Grooved hard copper wire	110 mm^2

(3) Lateral zigzag deviation (strand 200 mm and maximum 250 mm) is given to the contact wire so that the pantograph collector can collect power constantly. But the standard deviation should be 100 mm on long bridges where strong winds are predicted.

(4) The standard height of contact wire above rail level is 5,200 mm, with a minimum of 4,800 mm and maximum of 5,500 mm.

The height of contact wire at road crossings should be determined by considering the loaded height of trucks. Caution signs should be provided at both sides of each road crossing.

(5) The standard distance of a section of contact line is 1,500 m.

(6) An automatic tensioning device is provided at the ends of each section of contact wire to compensate for expansion and contraction of the wire due to temperature changes keeping the tension constant.

The automatic tensioning devices are of the pulley type on the main tracks and important side tracks of 600 m or longer. Spring type devices are used in important side lines of less than 600 m in distance.

(7) Sectioning device

The parallel portions of adjacent sections of main line contact wire are provided with air sectioning isolators. The insulation of the up and down double tracks in station depot is effected with fiber reinforced plastic insulators on which the pantograph collector can slide.

3. Feeder

The feeding system is generally isolated in each operating section, up and down-tracks and branch lines. The feeder is retained with brackets attached to contact line supports.

Voltage	:	1,500 VDC
Wire	:	Hard aluminum stranded wire (with two strands of 510 mm^2 each), one circuit for up and one for down track
Standard tension:		700 kg

Feeding system diagrams are given in Figs. 6-9-3, 6-9-4.

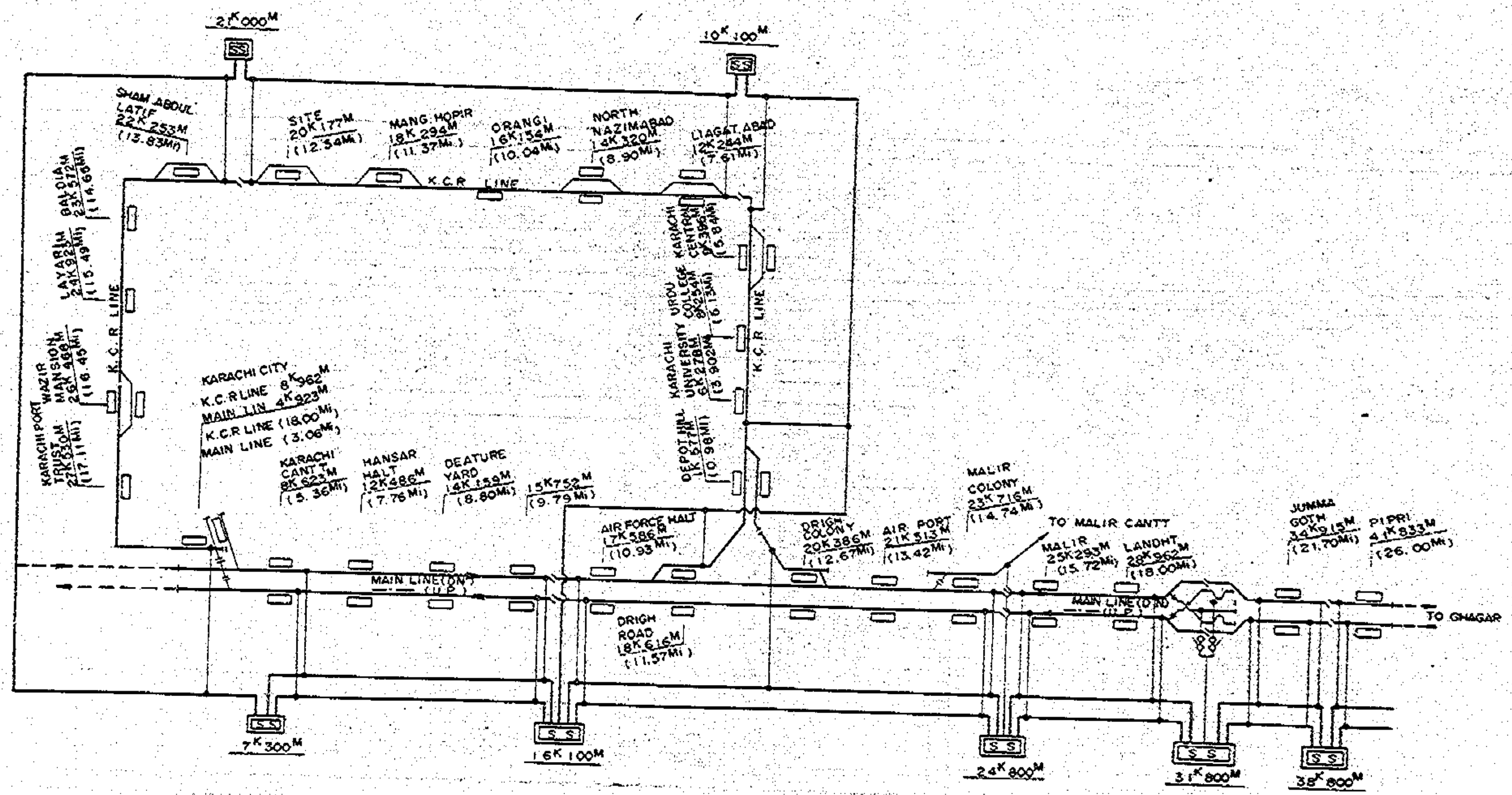


Fig. 6-9-3 Feeding System Diagram (Phase 1)

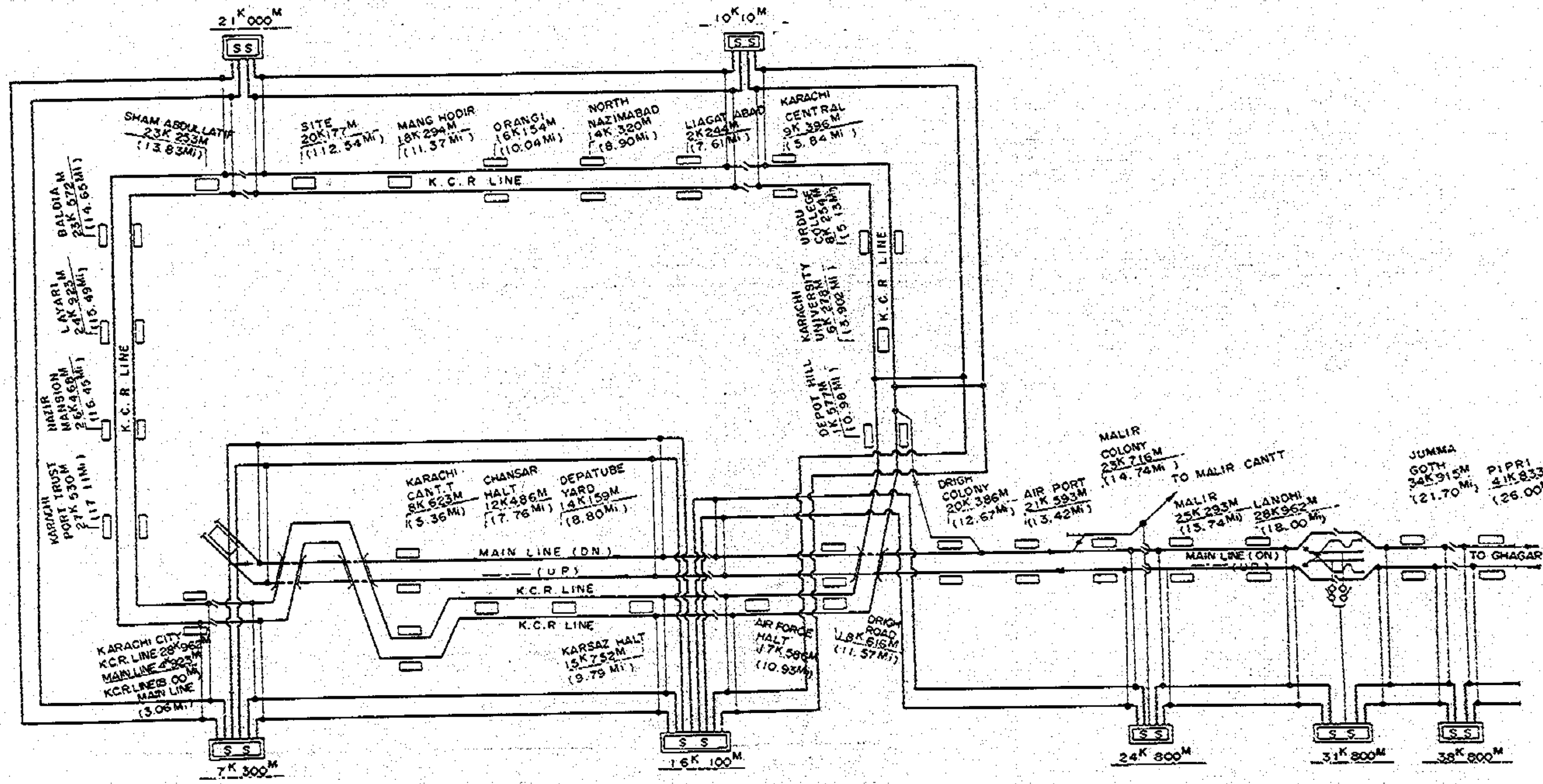


Fig. 6-9-4 Feeding System Diagram (Phase 2)

4. Insulation

The quality of insulation of each conductor and insulators used are shown in Table 6-9-3-3.

Table 6-9-3-3 Use of insulators

Conductor	Place of use	Insulator		
		Type	Number of element	Surface leakage distance
Feeder	Held with cross-arms	180 mm suspension	2	360 mm
Contact line	Main track	Stems (AN-2 and BN-2 for hinged cantilever	1 each	600 mm
	Side track (directly suspended from brackets)	180 mm suspension	2	360 mm

5. A feeder section is normally 250 m.

6. Lightning arresters are normally provided at intervals of 500 m.

6-10. High Voltage Distribution Lines

6-10-1 Purpose and construction plan (Figs. 6-10-1, 6-10-2)

High voltage distribution lines, which are exclusively used for supplying power to signals and other ground facilities of the railway, are constructed in parallel with railway tracks.

The distribution lines of the main line consist of a distribution main line of 38 km between Karachi City and Pipri and branch lines of 8 km between Malir Colony and Malir Cantt and of 2 km in Landhi Depot.

The distribution lines of K.C.R. consist of a 32 km main line from Drigh Road to Karachi City via Site and a 2 km branch line between Depot Hill and Drigh Colony.* The construction of all distribution lines is scheduled to be finished under Phase 1 and after that additional con-

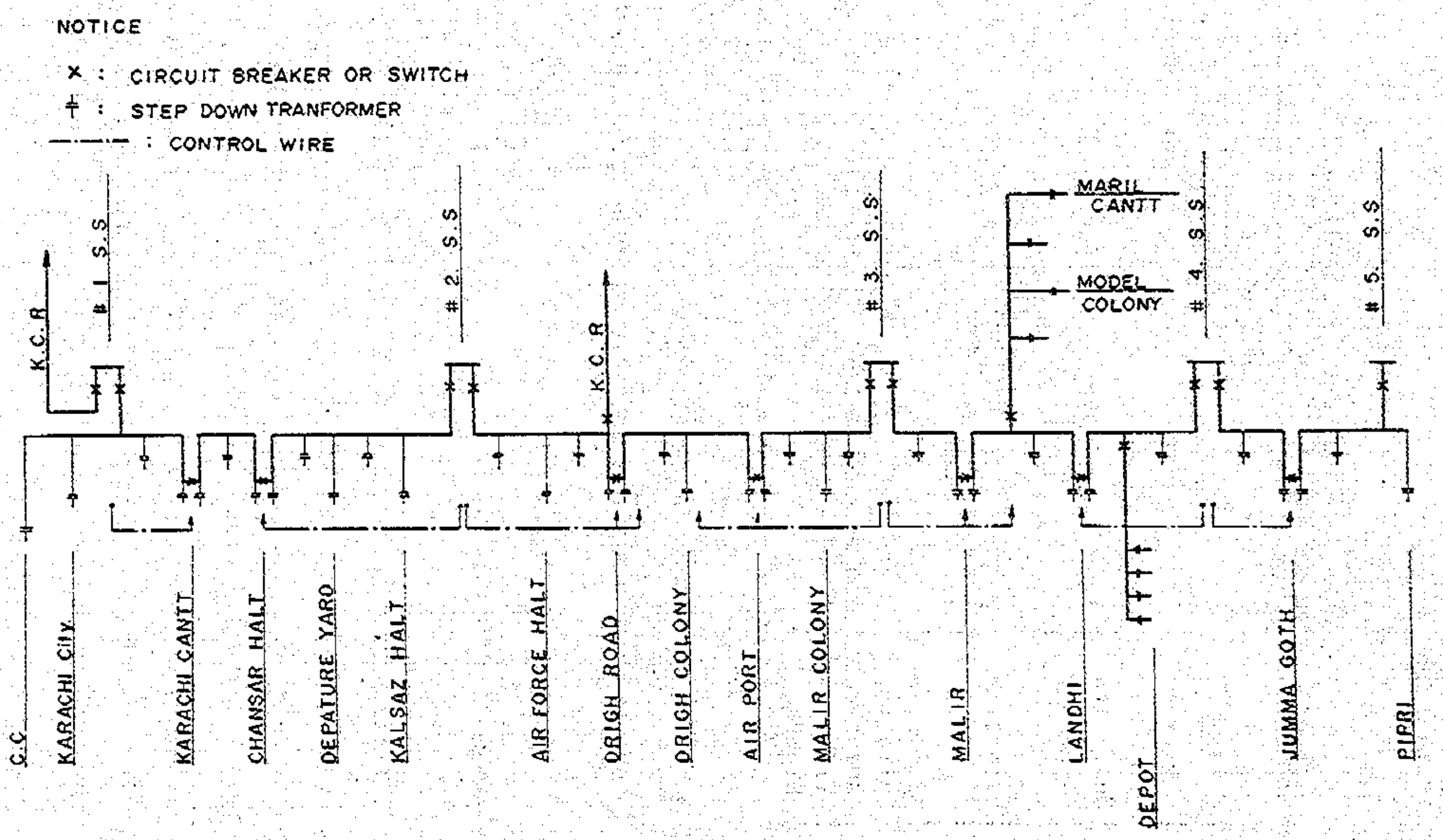


Fig. 6-10-1 Line MAP of 6.6^{kV} Distribution Line (Main Line)

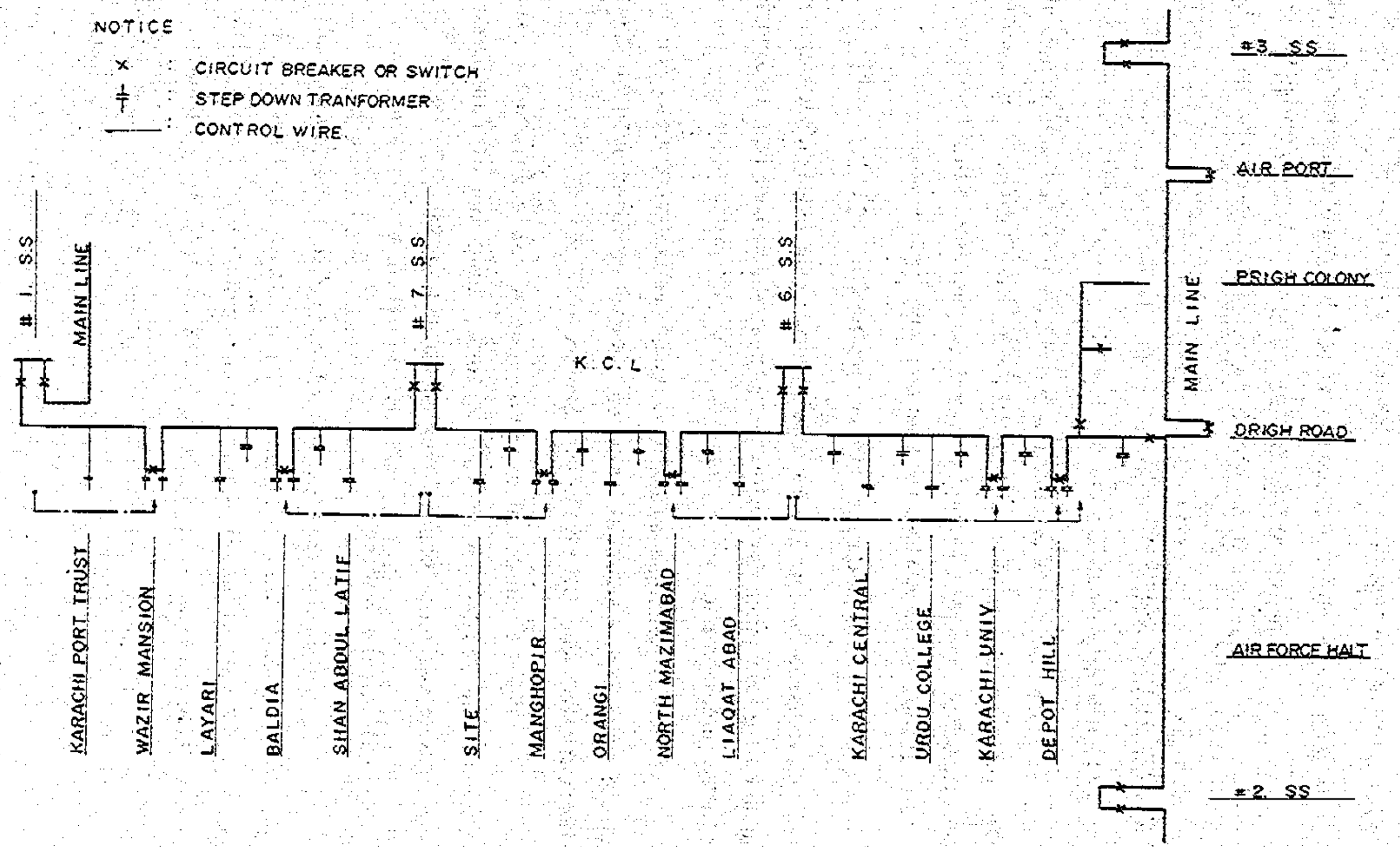


Fig. 6-10-2 Line MAP of 6.6^{kV} Distribution Line (K.C.R.)

struction for improvement may follow the railway.

* Note: If the K.C.R. line is to be doubled, the distribution line constructed for the main line should be used for the new line which is parallel with the main line.

6-10-2 Outline of construction

(1) Supply points

The seven substations which we plan to construct should supply power to the high tension distribution lines. We consider that it should be possible to supply power to the distribution line between two substations from either of the two substations.

(2) Type of current and construction

Three-phase 6.6 kV current is transmitted through 3-wire ungrounded high tension distribution lines which are mostly overhead and partially underground.

The overhead lines are mostly suspended from the contact line supports except for special sections where poles should be installed exclusively for the distribution lines.

Use of conduits or cable ducts for underground lines is limited to the lead-outs of substations, lead-ins of equipment and places where overhead structures cannot be used.

(3) Safety devices

Protective relays and circuit breakers installed in substations protect the contact lines. In addition to these, a porcelain insulator is installed at each branching point of branch lines and between traction substations to isolate a section suffering trouble.

The porcelain insulator is under remote control and for this purpose a control cable is installed from the nearest substation.

The overhead high voltage distribution line is suspended from poles resistant to damage from salt and lightning arresters are provided therefor.

6-10-3 Loads of the distribution lines

(1) Loads

The loads to which the high voltage distribution lines supply power are signalling systems (in and between stations), electrical installations of buildings and lighting facilities in the yard of the electric car depot, electrical installations of the building of the control center, electrical installations of buildings of maintenance sections (signal, power, etc.), stations planned to be constructed and power to be consumed by substations.

The electrical installation of car workshop and existing stations or yards should receive power directly from K.E.S.C.

(2) Distribution capacity

1) A substation should have a distribution capacity sufficient to supply power to all loads existing between the substation and the adjacent substations.

2) A distribution line should have such a capacity that it cannot only supply power to all loads existing between two neighboring substations but the maximum voltage drop must not exceed 10% of the nominal line voltage even under the worst conditions.

3) Under normal conditions (or when the substations and distribution lines are not suffering from trouble) the distribution load capacity of a substation is about half of the maximum supply capacity. (See 6-10-4.)

(3) Balance between loads

Since the signal loads consume single-phase power, the line between two substations are divided into 3 blocks to keep the balance between the loads by making the load capacity of each block about equal and phase connections are alternated to prevent unbalance of loads between phases.

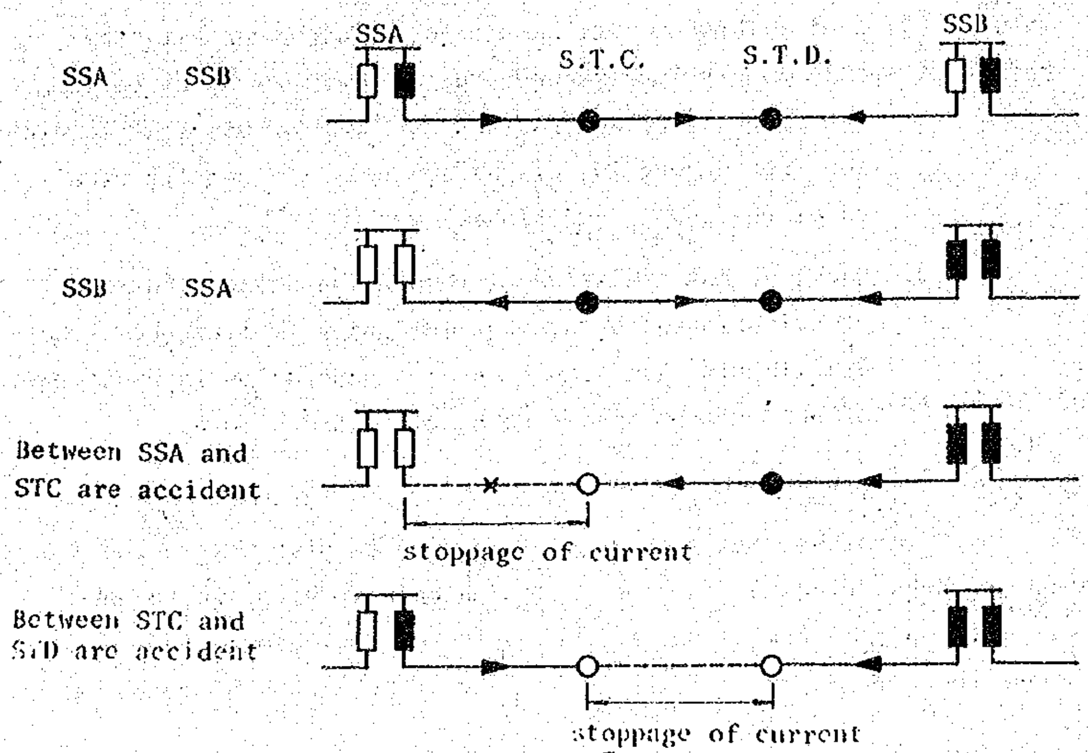
6-10-4 Operation of the high voltage distribution lines

A high tension distribution line is supplied with power from either of two neighboring substations as already mentioned. One of the two substations (say substation A) is normally supplying power to the line up to the other substation (substation B). But if service to substation A is interrupted, the circuit breaker of substation B is automatically closed so as to supply power to the line between substations B and A. If trouble has occurred midway along a distribution line, trial distribution is performed to localize the section where the trouble has occurred by opening the section switches on the line in sequence before resuming distribution for the remaining normal sections after opening the switches (or circuit breakers) which isolate the section in which trouble has occurred.

The scheme of distribution described above is shown below.

Note: The above operation cannot be done in sections such as branch lines where a single substation supplies power to each section.

Operation of Voltage Distribution



6-11. Electrical Installations of Railcar Depot and Stations

6-11-1 Incoming facilities

(1) Receiving power source of signals

The signals receive power from transformers for signals installed in station depot or between stations.

The input equipment of a signal in a station depot is a transformer box installed near the signal relay room.

The input equipment of a signal between stations is a transformer for the signal installed on contact line pole near the relay box.

The transformer for signals is provided with a high and low voltage separator plate and its secondary side is insulated from the ground.

At the station where the section switch described in (3) of 6-10-2 is provided, the switch is contained in a signal power transformer box. The switch is installed in between two signal power transformers of the same capacity. Automatic changeover switches are provided at the transformers' secondary sides to prevent interruption of signal power due to operation of the switch.

When the doublingof the K.C.R. track is completed, additional signals can use the existing signal power sources between stations if they are near to the signals. A signal power input equipment between stations should be installed additionally only if a low tension line must be extended over a long distance in unfavorable circumstances.

(2) Power input facilities (Fig. 6-11-1)

For buildings and lighting facilities scattered in the electric car depot, several sets of cubicle type input equipment containing circuit breakers, switches and a transformer is installed for each group of loads. Loads away from the incoming facilities are supplied with power through low tension distribution lines described below.

(3) Low voltage distribution lines (Fig. 6-11-1)

The low voltage distribution lines consist of overhead distribution lines suspended from the contact wire or high voltage line poles or from special poles and underground distribution lines.

6-11-2 Outdoor lighting facilities

Outdoor lighting facilities are installed for the tracks of the railcar depot and in other necessary places.

The depot track is lighted with discharge lamp floodlights (high pressure mercury or sodium vapor lamps) installed on lighting towers with an average horizontal brightness at the track surface of about 2 lux. (See Fig. 6-11-1).

Passages in the depot and other places where the floodlights do not cover are lighted independently with discharge lamps. At the car washing tracks, the sides of railcars should be illuminated with sufficient brightness (more than 10 lux).

6-11-3 Electrical installations in buildings

(1) Electrical installations in repair track shed and offices

General lighting in inspection and repair sheds is overall lighting (with an average brightness of 100 lux or more) which is suitable with a high ceiling and auxiliary lights illuminate the sides of cars at almost the same brightness. A light (of 100 lux or more) is provided in each floor pit for the inspection of the bottoms of railcars and outlets are conveniently provided for special inspection lights and electric tools. It is almost the same as this in repair shops. Electric machines such as cranes, lifts, air compressors, fans and pumps, should be provided with necessary power distribution facilities.

(2) Electrical installations in offices

Office buildings are provided with lights, outlets and necessary distribution facilities together with wiring for air conditioners. (Average brightness: 300 lux or more)

(3) Platforms

Additional platforms accompanying the doubling of the K.C.R. track are provided with necessary lighting and distribution facilities. (Average brightness: 100 lux or more)

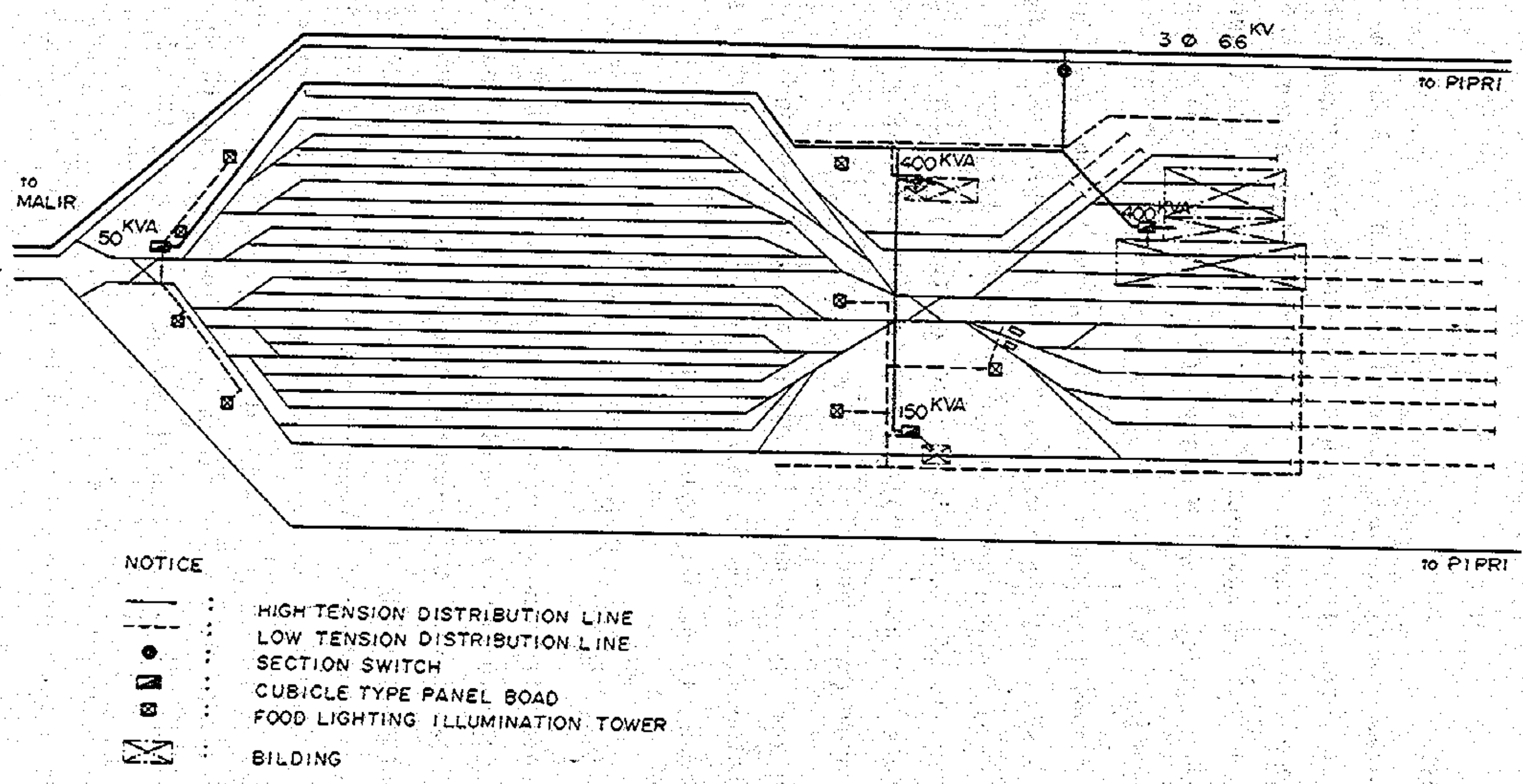


Fig. 6-11-1 Line MAP of Distribution Line (Landh Depot)

6-12. Improvement of the existing signal system

6-12-1 Signals

The block system between Karachi City and Pipri on the main line is currently an automatic system, but the stations of Jumma Goth and Pipri have not yet been fully automated. To enable frequent service using electric cars after the completion of electrification, we propose to change the block section length and to fully automate the signals in the yards of Jumma Goth and Pipri stations.

The headway is planned to be 10 minutes in 1982 and 6 minutes in 2002. But we selected the block section length which suits the headway of 6 minutes from the beginning so as to prevent backward work. In this case, the intervals of block signals are designed so that trains can be operated at intervals of 3 minutes, considering the problems of establishing of train operation schedule.

The signal system uses the currently used two-position (R and Y) or three-position (R, Y and G) signals generally and YY or YG position is added, if necessary, to the signal of small block sections.

6-12-2 Track circuit

DC track circuits are used at present, but it is necessary to change them after the electrification project is carried out using DC power, since the DC traction current will mix with the signal current flowing through the track circuit. Corresponding to DC electrification, we propose to install 50 Hz track circuits of which the cost of construction is low and maintenance is easy. Here double rail track circuits are provided for the main running line between stations and in station yards while single rail track circuits are provided for other places. The scheme of the track circuits is shown in Figs. 6-12-1-1 and 6-12-1-2.

When implementing the track circuits, welded bonds are fitted at the rail joints where return currents flow and impedance bonds are fitted at insulated rail joints.

6-12-3 Interlocking equipment

Relay interlocking equipment is installed in the yards of most

Fig. 6-12-1-1 Double Rail Track Circuit

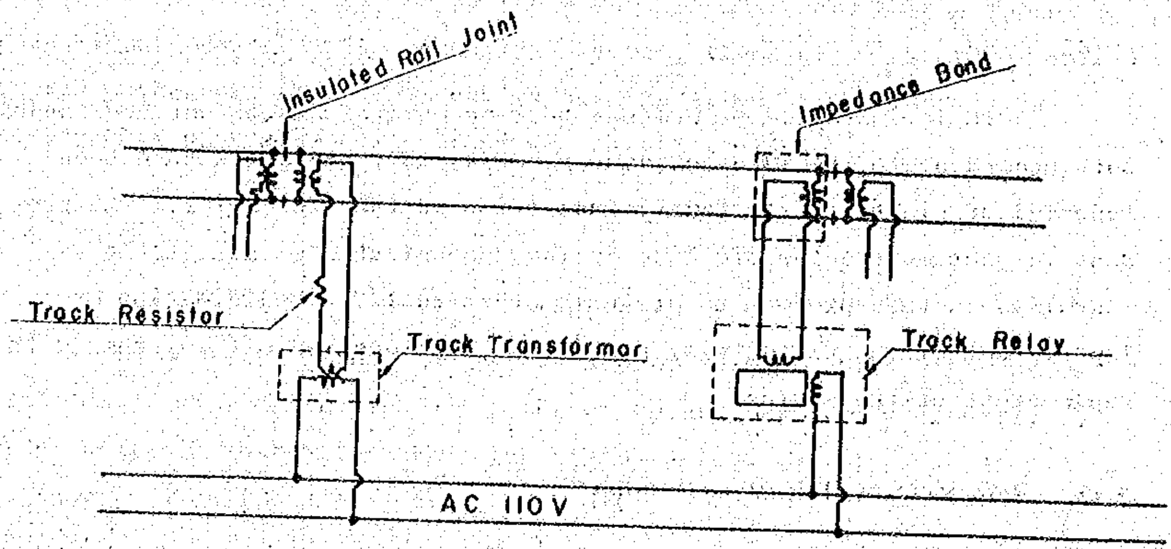
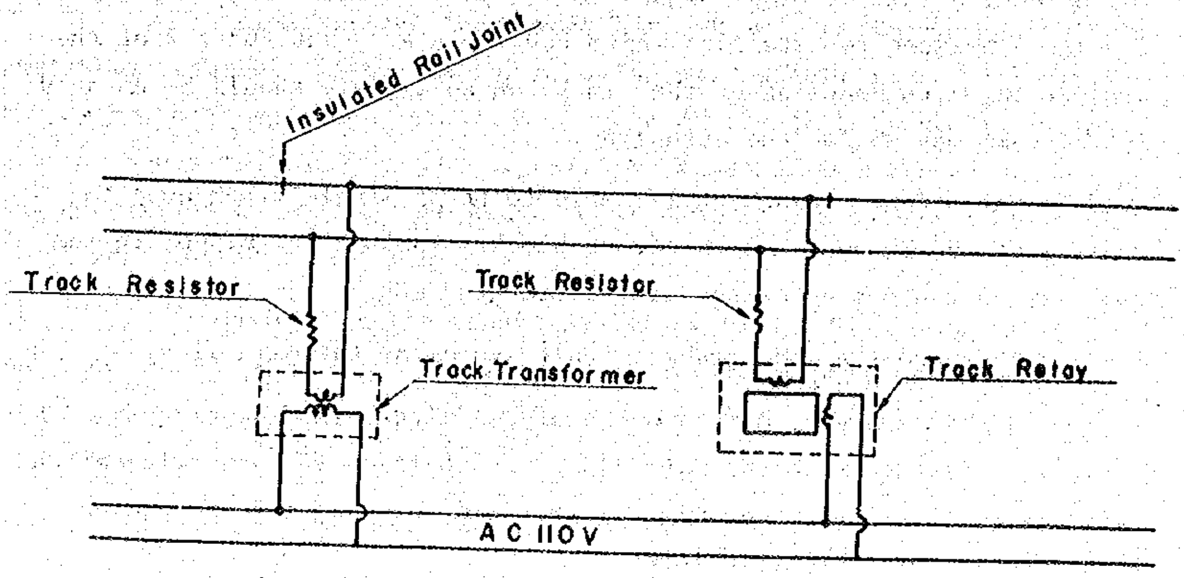


Fig. 6-12-1-2 Single Rail Track Circuit



stations on the main line but the equipment must be changed or improved when track relays are replaced accompanying the modification of the wiring in the yards and of the track circuits. Relay interlocking equipment has been newly installed in the Jumma Goth and Pipri stations.

6-12-4 CTC

CTC is installed at present between Karachi Cantonment and Landhi. But, according to the 1974 accident records, many accidents have been reported originating from faulty indication in the CTC cables. We propose to accommodate the CTC line in the communications cable to be installed in this project to prevent such trouble. Modification or improvement of the CTC display panel should be carried out together with replacement of the wiring.

6-13. Improvement of signalling facilities

6-13-1 KCR and Malir Cantt Branch

Semaphor signals equipped in KCR and Malir Cantt Branch are to be changed to automatic signals when the electrification project is completed.

Since the project of KCR does not involve doubleing of the track in Phase 1, a unit of block signal is equipped in each of the up and down tracks in between two stations which have points. But Phase 2 of the project involves doubling of the track and so signals should be changed in the same way as for the main line.

Malir Cantt Branch will remain to be of single track even in Phase 2 of the Project and therefore block signals are equipped in the same way as the system of the single track of KCR.

They use the same track circuit system as the main line.

Stations having points are equipped with relay interlocking devices. Branches from the main line are provided with electric switch mechanisms, but those used only for switching or shunting are equipped with levers having electric locks.

Generally the control panel of the relay interlocking equipment is installed in the station office and relay racks are accommodated in a newly made relay room.

6-13-2 Electric car depot

Shunting movement of cars in the area of the electric car depot is carried out with switching signals, which are operated by the relay interlocking device equipped in the signal cabin. For this purpose, a relay interlocking device, shunting signals, track circuits, electric switch mechanisms and signal cables are installed in the yard. The arrangement of these devices is shown in Fig. 6-13-1.

6-13-3 ATS

(1) Necessity of ATS

When a signal indicates stop or a restriction, the Automatic Train Stop (ATS) device activates the emergency brake automatically to stop the train just before the stop signal unless the operator stops the train or reduce its speed below the limit.

It is an essential means for safeguarding the train against accidental lack of concentration on the part of the operator to secure the safe operation of trains as speeds and traffic density become more and more high.

(2) Type of ATS

The ATS system is roughly divided into the point control and continuous control types, the former being more widely used. Concerning the method of comparison between the speed of the train passing a signal and the speed indicated by the signal, two kinds of systems are used. The comparison is made by the ground equipment in one system while the other performs it in the car.

Considering the conditions of extremely high temperatures and sandstorms, we use the latter type of ATS which performs detection or comparison of speed in the car, which is also favorable since this system is not so complicated and maintenance is easy.

Fig. 6-13-2 is a block diagram

The system we use is a point control frequency conversion type for which ATS wayside coils are installed near each signal and at a certain point before each signal to transmit the signal information to the passing car on which speed checking is done using the information.

Fig. 6-13-1 Signal Arrangement of Signalling Equipment in Depot

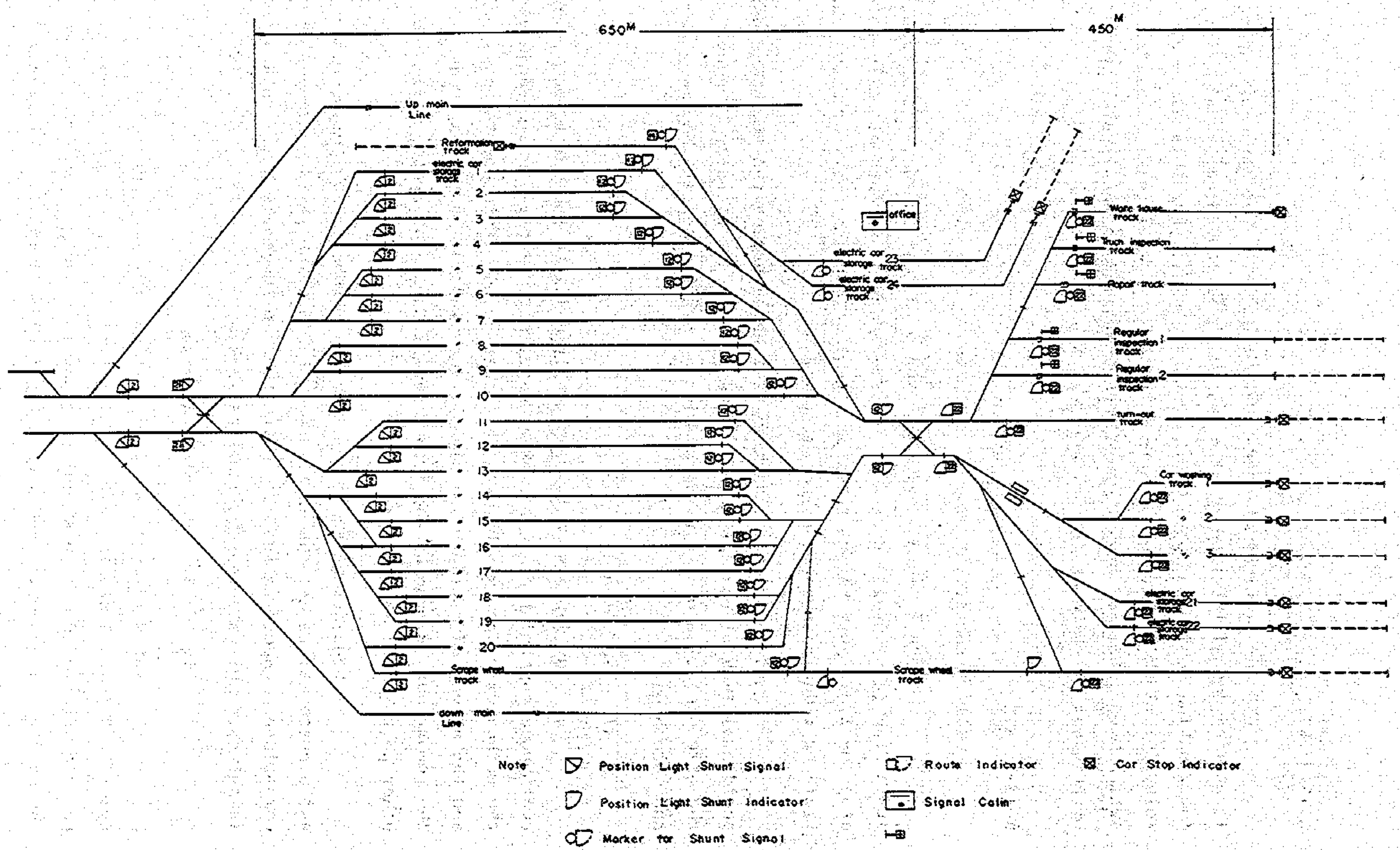
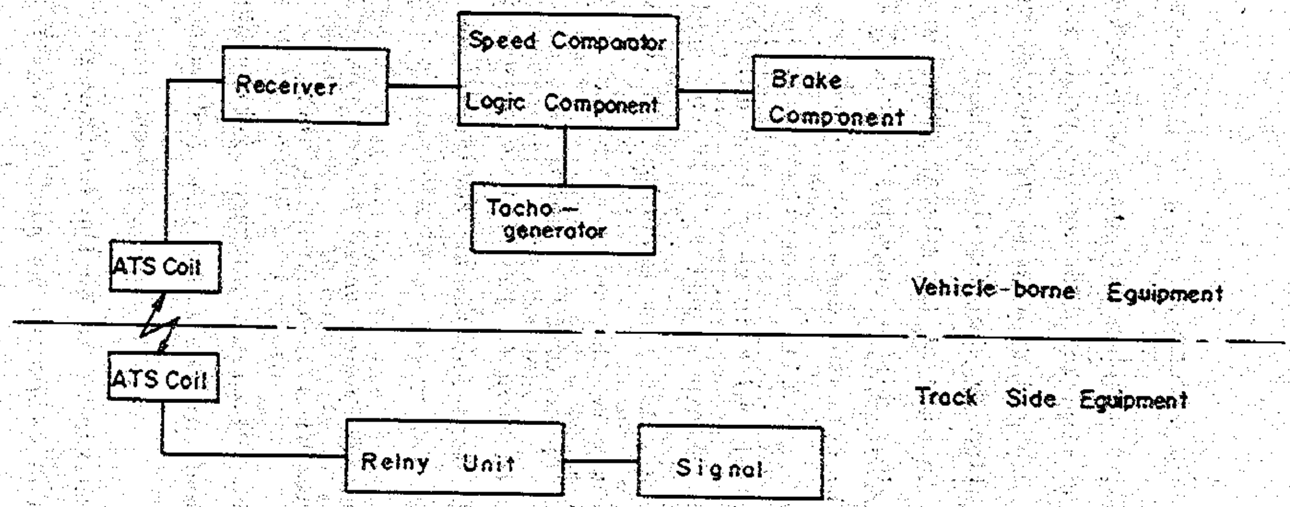


Fig. 6-13-2 <u>Block Diagram of ATS</u>



(3) Outline of ATS operation

Fig. 6-13-3 is a schematic diagram of ATS operation which shows the relationship of signals, ATS wayside coils and train speed curves. Symbols a, b, c and d represent ATS wayside coils which send speed information controlled by the signals to trains. Let us assume that trains A and B are running at the places shown in the diagram at a given moment. Then train B must reduce its speed to V1 before it comes to signal 2. But if the operator does not reduce the train speed to below V1, the emergency brake will be applied to train B at location b and the train, the speed of which is shown by a dotted line in the figure, will come to a stop just before signal 3. If the train is operated correctly as shown by the solid line according to the indications of signals, ATS does not activate the emergency brake. Even when the train has passed signal 2 at a speed of V1 or below, the emergency brake will be applied to the train to stop it just before signal 3 which is indicating stop if the operator does not reduce the train speed to below V2 at location C.

In any case, the emergency brake is activated if the train should pass location d since signal 3 is indicating stop.

According to the KDA plan, trackage right operation between the existing railways and each of the R/T, spine and extension lines is under consideration.

Since ATS is considered to be the minimum requirement to secure the safety of underground railways, we plan to implement ATS for the main line and KCR under Phase 2.

6-14. Improvement of Safety Device of Level Crossing

Most level crossings are equipped with gates at present. Some level crossings not equipped with nearby outer signals are equipped with gate signals. Before a train passes through a level crossing, a gate signal lever is operated, assuming the level crossing is closed with gates, to deliver a proceed signal to allow the train to go through the level crossing. This method, however, requires a great deal of time for lever operation and so it may not be used if the headway becomes small. For this reason, we propose to use the system currently used by JNR.

Fig. 6-14-1 is a schematic diagram of the system we propose.

The barrier rotates through 90° in the vertical plane to shut off the road when a train is passing the level crossing. The special flashing signal is to inform the train operator of an emergency, operated by the gate man flashing two pairs of red lamps on and off as shown in Fig. 6-14-2, in such cases as when a motorcar has come to a standstill on level crossing due to engine trouble or any other causes.

Under normal conditions, the level crossing alarms start ringing automatically a certain time before a train comes to the level crossing and a few second after that the barriers start swinging over the road to shut it off. The devices restore to their initial state when the train has passed through the level crossing. If an emergency happens on the level crossing, the gate man operates the special flashing signal switch to inform the train operator of the emergency.

We propose an alternative for KCR to abolish the level crossings by elevating the railroad partially as described in Chapter 5. The existing freight line of each station is left as it is together with the signal and crossing facilities. At both ends of the elevated track, points are provided so the goods trains can run on the existing line while passenger trains run on the elevated track.

6-15. Reform of Telecommunication Facilities

6-15-1 Telecommunication lines

Information will necessarily increase when the electrification project has been completed and various facilities have been modernized.

It will be difficult for the telecommunication lines available at present (1975), which consist mainly of bare wires, to deal with information which will increase more and more in the future and to transmit it at high quality.

For this reason, we propose to change all the telecommunication lines of the electrified sections to cable tele lines.

The telecommunication lines use composit foamed polyethylene insulated aluminum-sheathed tape-armored anti-corrosion cable (XTEFE TAZE) mainly.

Fig. 6-13-3 ATS Control Curve

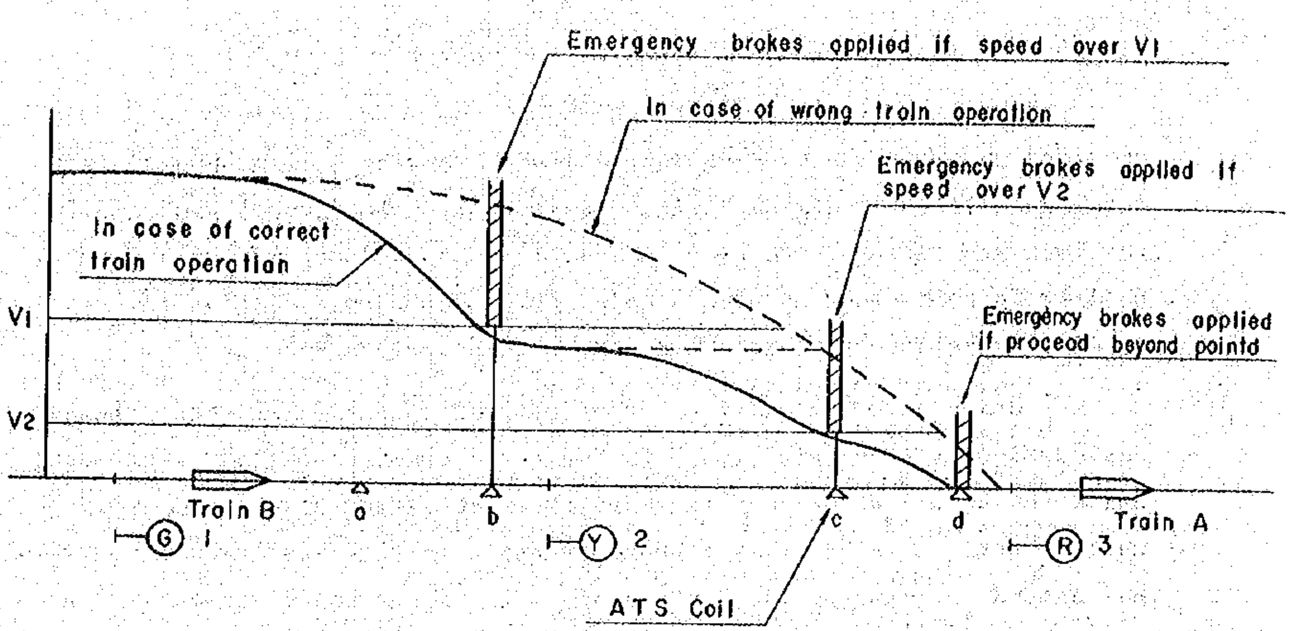


Fig. 7-14-1 General Arrangement of Level Crossing

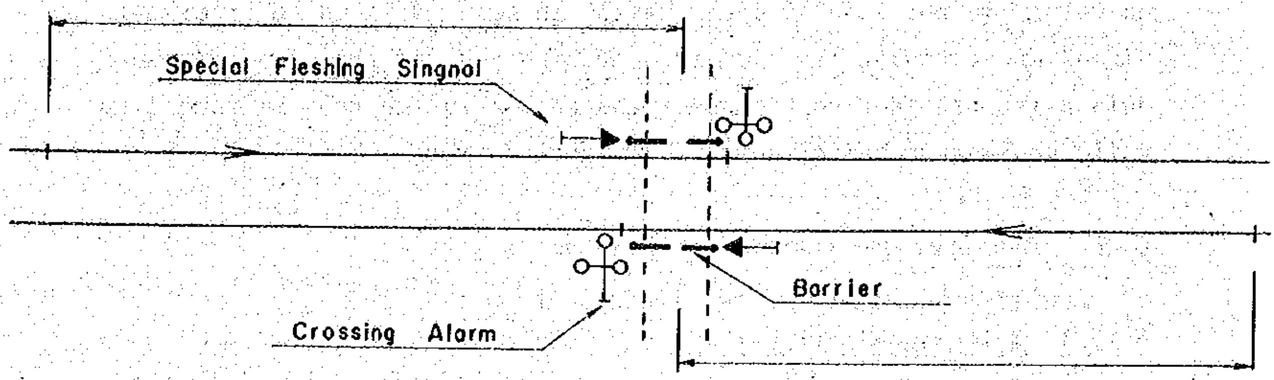
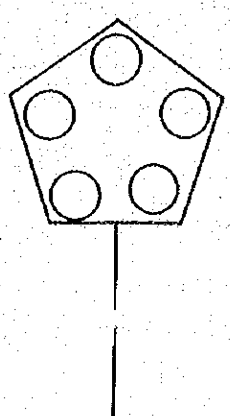
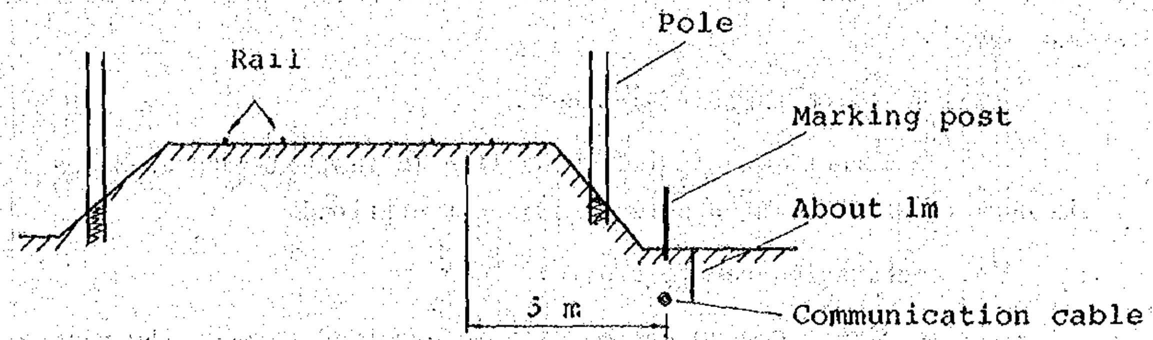


Fig. 7-14-2 Special Flashing Signal



The cable is contained in troughs in the yard of stations and buried directly in the ground between stations with marking posts installed right over the buried cable at intervals of 500 m.



In addition, a device which supplies dry air into the cable at a certain pressure is installed to help daily checking and finding cable malfunctions easily.

6-15-2 Carrier-current telephony equipment

Two circuits of carrier-current telephony equipment (with a capacity of 12 channels) are installed between Karachi City and Landhi to form a standard quality telecommunication line by compensating for the transmission loss of the cable telecommunication lines Carrier repeaters are installed at Chansar Halt and Drigh Road.

6-15-3 Control telephone

The F-1 type (JNR) control telephone sets are used and connected to the power control and operation control lines.

The control telephone sets currently used should be removed and diverted to the sections not electrified. The control center is equipped with the control telephone master device.

6-15-4 Other communication lines

(1) Wayside telephone

Telephone sets are installed along the electrified railroad at intervals of 500 m. This telephone line accommodates circuits used for communications with trackmen and emergency communications.

(2) Talk-back equipment

Talk-back equipment is provided for the purpose of communications (between signal cabins and points) when shunting cars in a station or car yard.

(3) Train operation telephone

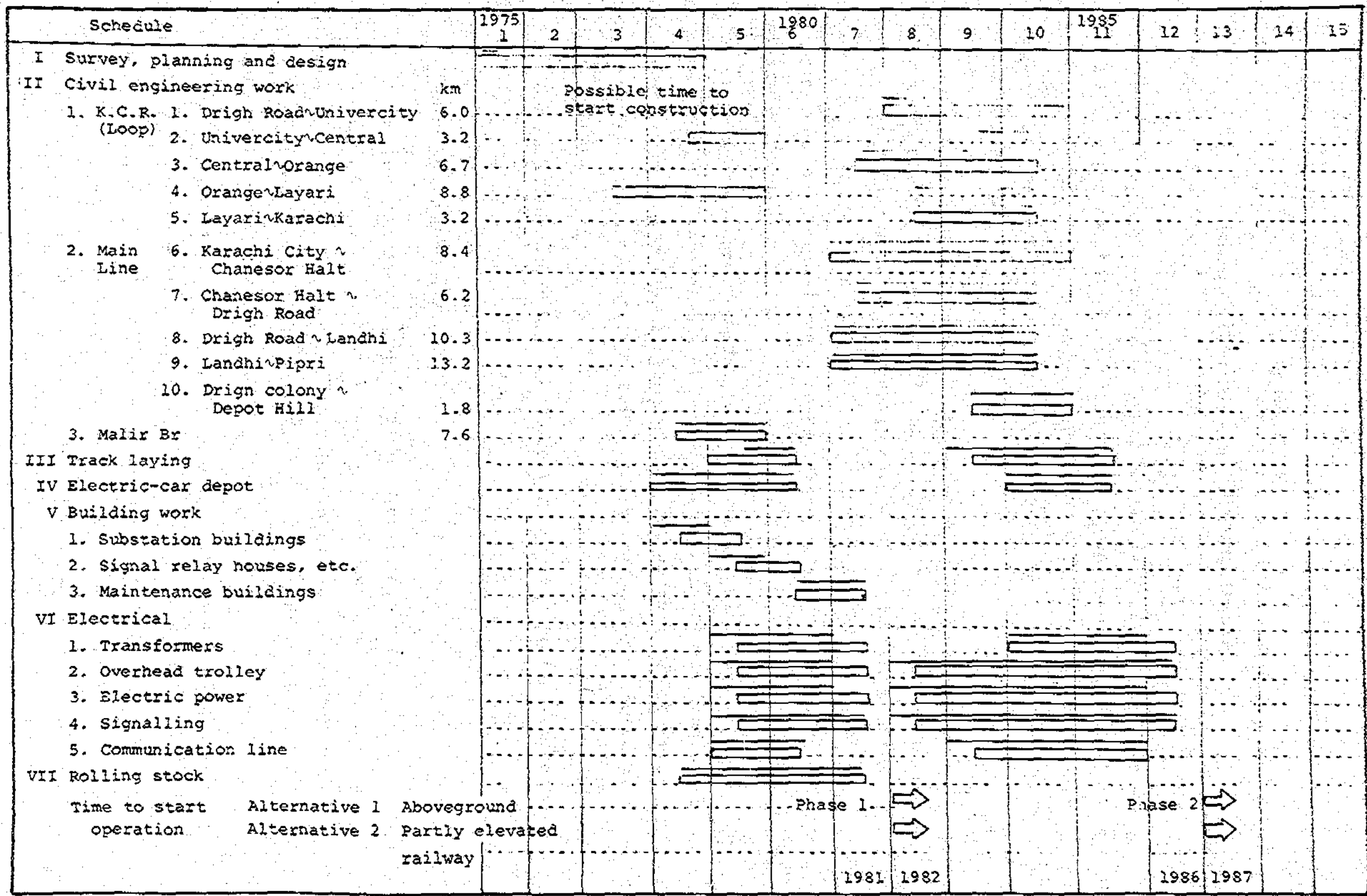
A direct magneto telephone line is installed to exchange train operation information between adjacent stations.

(4) Substation remote control lines

A direct communication line is provided between the control center and each substation to put the traction substation under remote control from the control center.

CHAPTER 7

Work Progress Schedule



CHAPTER 8

Administration and Management

According to the results of this feasibility study, the demand for traffic in the Karachi Metropolitan Area in the year 1987 is estimated to be 4.2 times (in terms of passengers) and 4.5 times (in terms of passenger-mileage) that of 1971 and in the year 2000 about 10 times and 11 times that of 1971.

In order to cope with this traffic demand, this study team proposed the remodelling and electrification of KCR to a double-track line and of the main line to a four-track line in series so as to modernize the existing railways. By doing this, in 1982 and 1987 the traffic capacities will be increased to a larger extent and the headways of trains considerably reduced.

On the other hand, however, a further study will have to be carried out with respect to the methods of administering and managing the staff and workers, whose number will increase with the services relating to the transportation, train operation, civil, electrical and maintenance divisions increases.

The following describes the concept as applied to the respective divisions.

8-1. Transportation and Train Operation

At present, staff related to train operation are marshalled under the leadership of station masters to handle daily duties. However, as traffic services will increase markedly in the future, more booking and train operation staff will be required and hence platform and ticket examiner must be managed accordingly.

The duty of platform staff is to make possible normal operation of trains and conduct passengers in the rush hours and that of ticket examiner is to check ticket and prevent fradulent passengers. In addition, as station masters alone cannot perform overall administration as the services increase, officials assisting station masters in the fulfillment of their services must be assigned. The addition of booking offices is also required in line with the increase of services, hence employment of automatic ticket machines has been envisaged.

Meanwhile, in the administrative division, the existing operation control system must be improved to a greater extent and additional passenger control systems must be provided to assure normal operation of passenger trains and when abnormal situation occurs, to arrange for proper transportation of passengers and transmit information from one station to another, all must be done rapidly.

As well as this, an organization must be established to enable safe operation of trains and protect passengers. For these purposes, conductor services must be integrated and inspection of tickets in coaches must be carried out at all times.

8-2. Concerning Civil Engineering Works

3 assistant engineers are assigned to a Divisional Civil Engineer within the administrative division. The train operation division consists of two sub-divisions; the track maintenance sub-division and maintenance of civil structures and buildings. Regular inspection is performed by a track, bicycle or on foot.

For this purpose, teams, each consisting of 15 - 20 track workers, perform maintenance of the trackway, according to the work schedule.

Considering faster trains and a large increase in the frequency of trains in the future, the wear and destruction of tracks must be considered and the safety of maintenance services will be threatened, therefore the following should be studied.

(1) Heavier rails must be used. Employment of long rails should be envisaged.

The existing manual maintenance services must be changed to mechanical services, and for this purpose a new maintenance method must be employed and train operations reshuffled. In order to effect the performance of drastic, complete maintenance services by sub-dividing the sections, the training of necessary staff must be promoted systematically so as to make progress in the modernization of maintenance services.

(2) In order to protect the safety of staff from the faster trains and increased train frequency, trains should be watched in a certain fixed pattern and a means to assure sufficient time for the carry-

ing out of large scale work should be provided. Unauthorized personnel should be kept away from entering the trackway by providing fencing at the boundary between the right of way and the outside area; this will contribute to the prevention of accidents.

8-3. Electrical

With respect to electrical facilities, the following organizations should be established to maintain electrical equipment.

The maintenance services being carried out concerning substation systems on the already electrified section between Lahole and Khanewal should preferably be consigned to KESC who has sufficient staff to perform this, and has stated that it would accept such consignment as a necessary service to be handled by it.

With respect to the maintenance of signals, Karachi Regional Office is carrying out maintenance of mechanical signals, level crossings, CTC of the main line and the automatic signal section between Karachi City and Pipri. However, more staff should be employed and trained to perfect maintenance services.

With respect to the communication system, other than the CTC section of the main line, no cables, etc. are owned by PR and no organization has been established to maintain such cables. However, Karachi Regional Office has an organization capable of maintaining and communications equipment such as telephone sets, signal transmitters, etc. and the cables in the CTC section, and this should be extended and improved so as to perform satisfactory maintenance.

With respect to management, it is considered to be sufficient for Karachi Regional Office to employ some more electrical engineers so as to strengthen the administrative division. However, the provision of a power control center to marshal electrical transformer facilities and high voltage distributors and a signal and communications center to marshal signals and communications systems should be located in the central area of Karachi-Cantt or Karachi City. For this purpose, each control center should preferably be manned with a staff of about two on a full-time basis.

CHAPTER 9

Investment Fund

9-1. Contents of Fund Program

For the execution of this Project, the investment of enormous sum will be required. Such an investment can be recovered only over a long period of time. Concrete annual fund plans should therefore be established.

For the authorities concerned with this Project, the total sum and that breakdown by individual application should be determined in detail. In addition, if a substantial portion of construction materials, equipment and machinery, rolling-stock, technology and other necessary services must be imported from a foreign country as is the case with this project, the required amount of foreign currency will constitute an important factor. In conclusion, the fund program for this Project can be summarized as is shown in Table 9-1 ∿ 9-4.

This fund program as shown in the tables is based on the assumed time schedule of construction work of this project obtained through deliberations among various experts.

9-2. Assumptions

The fund program mentioned in Paragraph 9-1 above has been estimated temporarily on the basis of the following assumptions, to which the Japanese Government has no objection.

(a) Equipment, machinery, parts, materials, rolling-stock and technicians not available in Pakistan are to be imported or furnished from Japan.

(b) Prices of imports from Japan are C.I.F. prices.

(c) Prices of imports from Japan do not include any customs duties nor business taxes.

(d) Compensation for any personal or corporate rights which may be affected by the execution of this Project as well as that for any rights of way are not included.

(e) Prices of equipment, machinery, parts, materials, rolling-stock, technical fees and wages adopted are those prevailing as of 1974.

9-3. Two Alternative Financial Programs

As shown in Table 9-1, two alternative financial programs were prepared. These alternatives correspond to the two proposals mentioned in Chapter 3 above; one for construction of bridge structures for elevated track for certain existing railway sections containing grade crossings with principal roads, and the other for modernization leaving the railway in its present condition. The latter proposal implies that all crossings on the existing railway are to be grade-separated (with roads being elevated) by the road management agency. Accordingly, the financial program for this proposal (Alternative 1 in Table 9-1) does not cover any funds required for grade-separation of such crossings.

Table 9-1 Fund Program by Years and by Local and Foreign Currencies for two alternative plans (interest not included)

Alternative 1

(In thousand rupees)

Year	Civil works			Electrical installations			Total		
	Local currency	Foreign currency	Sub-total	Local currency	Foreign currency	Sub-total	Local currency	Foreign currency	Total
1975					1,833.3	1,833.3		1,833.3	1,833.3
1976					3,666.7	3,666.7		3,666.7	3,666.7
1977	61,933.3	41,466.7	103,400.0		3,666.7	3,666.7	61,933.3	45,133.3	107,066.7
1978	134,000.0	90,333.3	224,333.3		57,933.3	57,933.3	134,000.0	148,266.7	282,266.7
1979	134,000.0	90,333.3	224,333.3	15,066.7	112,666.7	127,733.3	149,066.7	203,000.0	352,066.7
1980	101,333.3	106,633.3	207,966.7	26,433.3	215,466.7	241,900.0	127,766.7	322,100.0	449,866.7
1981	71,366.7	98,566.7	169,933.3	14,533.3	67,166.7	81,700.0	85,900.0	165,733.3	251,633.3
1982	95,100.0	131,500.0	226,600.0	866.7	10,633.3	11,500.0	95,966.7	142,133.3	238,100.0
1983	118,733.3	164,466.7	283,200.0	2,366.7	20,766.7	23,133.3	121,100.0	185,233.3	306,333.3
1984	118,733.3	164,466.7	283,200.0	3,266.7	30,466.7	33,733.3	122,000.0	194,933.3	316,933.3
1985	24,366.7	33,300.0	57,666.7	5,833.3	62,766.7	68,600.0	30,200.0	96,066.7	126,266.7
1986				3,100.0	14,900.0	18,000.0	3,100.0	14,900.0	18,000.0
Total	859,566.7	921,066.7	1,780,633.3	71,466.7	601,933.3	673,400.0	931,033.3	1,523,000.0	2,454,033.3

Alternative 2

Year	Civil works			Electrical installations			Total		
	Local currency	Foreign currency	Sub-total	Local currency	Foreign currency	Sub-total	Local currency	Foreign currency	Total
1975					1,833.3	1,833.3		1,833.3	1,833.3
1976					3,666.7	3,666.7		3,666.7	3,666.7
1977	152,666.7	239,266.7	391,933.3		3,666.7	3,666.7	152,666.7	242,933.3	395,600.0
1978	292,500.0	436,833.3	729,333.3		57,933.3	57,933.3	292,500.0	494,766.7	787,266.7
1979	292,500.0	436,833.3	729,333.3	15,066.7	112,666.7	127,733.3	307,566.7	549,500.0	857,066.7
1980	142,000.0	202,500.0	344,500.0	26,433.3	215,466.7	241,900.0	168,433.3	417,966.7	586,400.0
1981	64,966.7	93,700.0	158,666.7	14,533.3	67,166.7	81,700.0	79,500.0	160,866.7	240,366.7
1982	86,600.0	125,033.3	211,633.3	866.7	10,633.3	11,500.0	87,466.7	135,666.7	223,133.3
1983	108,066.7	156,400.0	264,466.7	2,366.7	20,766.7	23,133.3	110,433.3	177,166.7	287,600.0
1984	108,066.7	156,400.0	264,466.7	3,266.7	30,466.7	33,733.3	111,333.3	186,866.7	298,200.0
1985	22,266.7	31,666.7	53,933.3	5,833.3	62,766.7	68,600.0	28,100.0	94,433.3	122,533.3
1986				3,100.0	14,900.0	18,000.0	3,100.0	14,900.0	18,000.0
Total	1,269,633.3	1,878,633.3	3,148,266.7	71,466.7	601,933.3	673,400.0	1,341,100.0	2,480,566.7	3,821,666.7

Table 9-1-(1) Fund Program by Years and by Local and Foreign Currencies --- for Civil Works

(In thousand rupees)

Alternative 1

Categories of work	By local & foreign currency	1975	1976	1977	1978	1979	1980	1981
KCR	Local currency			20,266.7	35,500.0	35,500.0	28,033.3	26,833.3
	Foreign currency			11,533.3	20,166.7	20,166.7	16,333.3	15,900.0
	Sub-total			31,800.0	55,666.7	55,666.7	44,366.7	42,733.3
M.L.	Local currency			41,666.7	73,000.0	73,000.0	50,466.7	44,533.3
	Foreign currency			29,933.3	52,333.3	52,333.3	70,300.0	82,666.7
	Sub-total			71,600.0	125,333.3	125,333.3	120,766.7	127,200.0
Malir Br.	Local currency				2,833.3	2,833.3		
	Foreign currency				1,166.7	1,166.7		
	Sub-total				4,000.0	4,000.0		
Electric car depot	Local currency				22,666.7	22,666.7	22,833.3	
	Foreign currency				16,666.7	16,666.7	20,000.0	
	Sub-total				39,333.3	39,333.3	42,833.3	
Total	Local currency			61,933.3	134,000.0	134,000.0	101,333.3	71,366.7
	Foreign currency			41,466.7	90,333.3	90,333.3	106,633.3	98,566.7
	total			103,400.0	224,333.3	224,333.3	207,966.7	169,933.3

Alternative 1

Categories of work	By local & foreign currency	1982	1983	1984	1985	1986	Total
KCR	Local currency	35,766.7	44,733.3	44,733.3	8,933.3		280,300.0
	Foreign currency	21,166.7	26,466.7	26,466.7	5,300.0		163,500.0
	Sub-total	56,933.4	71,200.0	71,200.0	14,233.3		443,800.0
M.L.	Local currency	59,333.3	74,000.0	74,000.0	15,433.3		505,433.3
	Foreign currency	110,333.3	138,000.0	138,000.0	28,000.0		701,900.0
	Sub-total	169,666.7	212,000.0	212,000.0	43,433.3		1,207,333.3
Malir Br.	Local currency						5,666.7
	Foreign currency						2,333.3
	Sub-total						8,000.0
Electric car depot	Local currency						68,166.7
	Foreign currency						53,333.3
	Sub-total						121,500.0
Total	Local currency	95,100.0	118,733.3	118,733.3	24,366.7		859,566.7
	Foreign currency	131,500.0	164,466.7	164,466.7	33,300.0		921,066.7
	total	226,600.0	283,200.0	283,200.0	57,666.7		1,780,633.3

Alternative 2

Categories of work	By local & foreign currency	1975	1976	1977	1978	1979	1980	1981
KCR	Local currency			111,000.0	194,000.0	194,000.0	68,700.0	20,433.3
	Foreign currency			209,333.3	366,666.7	366,666.7	112,200.0	11,033.3
	Sub-total			320,333.3	560,666.7	560,666.7	180,900.0	31,466.7
M.L.	Local currency			41,666.7	73,000.0	73,000.0	50,466.7	44,533.3
	Foreign currency			29,933.3	52,333.3	52,333.3	70,300.0	82,666.7
	Sub-total			71,600.0	125,333.3	125,333.3	120,766.7	127,200.0
Malir Br.	Local currency				2,833.3	2,833.3		
	Foreign currency				1,166.7	1,166.7		
	Sub-total				4,000.0	4,000.0		
Electric car depot	Local currency				22,666.7	22,666.7	22,833.3	
	Foreign currency				16,666.7	16,666.7	20,000.0	
	Sub-total				39,333.3	39,333.3	42,833.3	
Total	Local currency			152,666.7	292,500.0	292,500.0	142,000.0	64,966.7
	Foreign currency			239,266.7	436,833.3	436,833.3	202,500.0	93,700.0
	total			391,933.3	729,333.3	729,333.3	344,500.0	158,666.7

Alternative 2

Categories of work	By local & foreign currency	1982	1983	1984	1985	1986	Total
KCR	Local currency	27,266.7	34,066.7	34,066.7	6,833.3		690,366.7
	Foreign currency	14,700.0	18,400.0	18,400.0	3,666.7		1,121,066.6
	Sub-total	41,966.7	52,466.7	52,466.7	10,500.0		1,811,433.3
M.L.	Local currency	59,333.3	74,000.0	74,000.0	15,433.3		505,433.3
	Foreign currency	110,333.3	138,000.0	138,000.0	28,000.0		701,900.0
	Sub-total	169,666.7	212,000.0	212,000.0	43,433.3		1,207,333.3
Malir Br.	Local currency						5,666.7
	Foreign currency						2,333.3
	Sub-total						8,000.0
Electric car depot	Local currency						68,166.7
	Foreign currency						53,333.3
	Sub-total						121,500.0
Total	Local currency	86,600.0	108,066.7	108,066.7	22,266.7		1,269,633.3
	Foreign currency	125,033.3	156,400.0	156,400.0	31,666.7		1,878,633.3
	total	211,633.3	264,466.7	264,466.7	53,933.3		3,148,266.7

Table 9-1-(2) Fund Program by Years and by Local and Foreign Currencies --- for electrical installations

(In thousand rupees)

Category of work		By local & foreign currency	1975	1976	1977	1978	1979	1980	1981
Electrical installations	Sub-stations	Foreign currency				16,100.0	14,233.3	104,766.7	7,100.0
		Local currency					833.3	6,966.7	400.0
		Sub-total				16,100.0	15,066.7	111,733.3	7,500.0
	Overhead trolley	Foreign currency				13,333.3	32,200.0	51,133.3	32,233.3
		Local currency					6,300.0	12,633.3	6,333.3
		Sub-total				13,333.3	38,500.0	63,766.7	38,566.7
	Electric Power	Foreign currency				6,666.7	11,733.3	12,166.7	4,666.7
		Local currency					833.3	1,500.0	2,500.0
		Sub-total				6,666.7	12,566.7	13,666.7	7,166.7
	Signaling	Foreign currency				13,333.3	23,333.3	23,333.3	15,533.3
		Local currency					2,666.7	2,666.7	4,000.0
		Sub-total				13,333.3	26,000.0	26,000.0	19,533.3
	Tele-communications	Foreign currency					19,466.7	3,200.0	
		Local currency					3,100.0	300.0	
		Sub-total					22,566.7	3,500.0	
	Sub-total	Foreign currency				49,433.3	100,966.7	194,600.0	59,533.3
		Local currency					13,733.3	24,066.7	13,233.3
		Sub-total				49,433.3	114,700.0	218,666.7	72,766.7
Engineering		Foreign currency	1,666.7	3,333.3	3,333.3	3,333.3	1,666.7	1,666.7	1,666.7
		Local currency							
		Sub-total	1,666.7	3,333.3	3,333.3	3,333.3	1,666.7	1,666.7	1,666.7
Total		Foreign currency	1,666.7	3,333.3	3,333.3	52,766.7	102,633.3	196,266.7	61,200.0
		Local currency					13,733.3	24,066.7	13,233.3
		total	1,666.7	3,333.3	3,333.3	52,766.7	116,366.7	220,333.3	74,433.3
Contingency		Foreign currency	166.7	333.3	333.3	5,166.7	10,033.3	19,200.0	5,966.7
		Local currency					1,333.3	2,366.7	1,300.0
		Sub-total	166.7	333.3	333.3	5,166.7	11,366.7	21,566.7	7,266.7
Grand total		Foreign currency	1,833.3	3,666.7	3,666.7	57,933.3	112,666.7	215,466.7	67,166.7
		Local currency					15,066.7	26,433.3	14,533.3
		total	1,833.3	3,666.7	3,666.7	57,933.3	127,733.3	241,900.0	81,700.0

Category of work		By local & foreign currency	1982	1983	1984	1985	1986	Total
Electrical installations	Sub-stations	Foreign currency			3,933.3	33,266.7	1,966.7	181,366.7
		Local currency			266.7	2,233.3	133.3	10,833.3
		Sub-total			4,200.0	35,500.0	2,100.0	192,200.0
	Overhead trolley	Foreign currency	5,133.3	10,400.0	10,400.0	10,400.0	5,166.7	170,400.0
		Local currency	733.3	1,466.7	1,466.7	1,466.7	733.3	31,133.3
		Sub-total	5,866.7	11,866.7	11,866.7	11,866.7	5,900.0	201,533.3
	Electric Power	Foreign currency	100.0	166.7	1,766.7	1,866.7	1,200.0	40,333.3
		Local currency	33.3	33.3	233.3	266.7	200.0	5,600.0
		Sub-total	133.3	200.0	2,000.0	2,133.3	1,400.0	45,933.3
	Signaling	Foreign currency	3,333.3	6,666.7	10,000.0	10,000.0	3,566.7	109,100.0
		Local currency		666.7	1,000.0	1,333.3	1,766.7	14,100.0
		Sub-total	3,333.3	7,333.3	11,000.0	11,333.3	5,333.3	123,200.0
	Tele-communications	Foreign currency	100.0					22,766.7
		Local currency	33.3					3,433.3
		Sub-total	133.3					26,200.0
	Sub-total	Foreign currency	8,666.7	17,233.3	26,100.0	55,533.3	11,900.0	523,966.7
		Local currency	800.0	2,166.7	2,966.7	5,300.0	2,833.3	65,100.0
		Sub-total	9,466.7	19,400.0	29,066.7	60,833.3	14,733.3	589,066.7
Engineering		Foreign currency	1,000.0	1,666.7	1,666.7	1,666.7	1,666.7	24,333.3
		Local currency						
		Sub-total	1,000.0	1,666.7	1,666.7	1,666.7	1,666.7	24,333.3
Total		Foreign currency	9,666.7	18,900.0	27,766.7	57,200.0	13,566.7	548,300.0
		Local currency	800.0	2,166.7	2,966.7	5,300.0	2,833.3	65,100.0
		total	10,466.7	21,066.7	30,733.3	62,500.0	16,400.0	613,400.0
Contingency		Foreign currency	966.7	1,866.7	2,700.0	5,566.7	1,333.3	53,633.3
		Local currency	66.7	200.0	300.0	533.3	266.7	6,366.7
		Sub-total	1,033.3	2,066.7	3,000.0	6,100.0	1,600.0	60,000.0
Grand total		Foreign currency	10,633.3	20,766.7	30,466.7	62,766.7	14,900.0	601,933.3
		Local currency	866.7	2,366.7	3,266.7	5,833.3	3,100.0	71,466.7
		total	11,500.0	23,133.3	33,733.7	68,600.0	18,000.0	673,400.0

Table 9-2-(1) Fund Plan by Local and Foreign Currencies and by Categories of Work --- for Electrical Installations

(In thousand rupees)

Categories of work	Items of work	Quantity	Foreign currency	Local currency	Total
Sub-stations	Sub-station facilities	7 places	181,367	10,833	192,200
Overhead trolley		254 km	170,400	31,133	201,533
Electric lighting & power	High-tension cable lines	129 km	23,767	3,067	26,833
	Electrical installations for bases, stations, etc.		16,567	2,533	19,100
	Sub-total		40,333	5,600	45,933
Signaling	Improvement of existing signaling facilities		28,800	4,067	32,867
	Modernization of signaling facilities		70,833	9,367	80,200
	Crossing safety and protection installations		9,467	667	10,133
	Sub-total		109,100	14,100	123,200
Tele-communications	Telecommunications lines		19,467	3,100	22,567
	Telecommunications equipment		3,300	333	3,500
	Sub-total		22,767	3,433	26,200
Engineering			24,333		24,333
Total			548,300	65,100	613,400
Contingency			53,633	6,367	60,000
Grand Total			601,933	71,467	673,400

Table 9-2-(2)-(1) Fund Plan by Local and Foreign Currencies and by Categories of Work --- for Civil Works

(In thousand rupees)

Categories of work	Items of work	Quantity	Local currency	Foreign currency	Total
(Alternative 1) K.C.R.	Track strengthening	27,700m	51,833	22,167	74,000
	Construction of new track structure	28,600m	46,600	20,067	66,667
	Safety and protection installations	30 places	2,000	2,000	4,000
	Station facilities		15,000	15,000	30,000
	Buildings for electrical installations		13,933	6,000	19,933
	Earthwork-filling	253,700m^3	40,333	4,500	44,833
	Earthwork-cutting	326,700m^3	33,233	3,700	36,933
	Temporary track	500m	1,800	767	2,567
	Run-over-type bridges	237m	6,333	25,333	31,667
	Bridge structures for elevated track	250m	8,500	19,833	28,333
	Bridges (small)	35.6m	1,000	633	1,633
	Bridges (medium)	192.3m	2,133	4,933	7,067
	Bridges (large)	344.0m	5,500	3,667	9,167
	Engineering		3,400	7,933	11,334
	Contingency		48,700	26,966	75,667
	Total		280,300	163,500	443,800

Table 9-2-(2)-(2) Fund Plan by Local and Foreign Currencies and by Categories of Work --- for Civil Works

(In thousand rupees)

Categories of work	Items of work	Quantity	Foreign currency	Local currency	Total
(Alternative 2) K.C.R.	Track strengthening	18,230m	34,000	14,667	48,667
	Construction of new track structure	37,570m	61,100	26,366	87,466
	Safety and protection installations	21 places	1,400	1,400	2,800
	Station facilities		3,167	3,167	6,333
	Buildings for electrical installations		13,933	6,000	19,933
	Earthwork - filling	209,340m^3	33,200	3,700	36,900
	Earthwork - cutting	326,700m^3	33,000	3,667	36,667
	Temporary track	2,810m	8,000	3,434	11,434
	Run-over-type bridges	237m	6,333	25,333	31,667
	Bridge structures for elevated track	8,390m	342,000	800,000	1,142,000
	Bridges (small)	18.8m	500	367	867
	Bridges (medium)	192.3m	2,133	4,933	7,066
	Bridges (large)	299.0m	3,667	5,500	9,167
	Retaining walls	1,080m	21,000	9,000	30,000
	Engineering		13,433	30,967	44,400
	Contingency		113,500	182,567	296,067
	Total		690,367	1,121,066	1,811,433

Table 9-2-(2)-(3) Fund Plan by Local and Foreign Currencies and by Categories of work --- for Civil Works

(In thousand rupees)

Categories of work	Items of work	Quantity	Local currency	Foreign currency	Total
Main Line	Track strengthening	72,950m	136,000	58,667	194,667
	Construction of new track structure	30,830m	59,333	25,333	84,666
	Safety and protection installations	12 places	3,133	3,133	6,266
	Station facilities		35,667	35,667	71,333
	Run-over-type bridges	570m	55,000	220,000	275,000
	Bridge structures for elevated track	1,770m	68,333	160,000	228,333
	Retaining walls	1,280m	17,967	7,700	25,667
	Bridges (small)	221m	6,200	4,133	10,333
	Bridges (medium)	48m	967	2,233	3,200
	Repair & improvement of highway bridges over railway		33,333	33,333	66,667
	Others		10,667	4,667	15,333
	Engineering		8,833	20,600	29,433
	Contingency		70,000	126,434	196,434
	Total		505,433	701,900	1,207,333

Table 9-2-(2)-(4) Fund Plan by Local and Foreign Currencies and by Categories of Work --- for Civil Works

(In thousand rupees)

Categories of work	Items of work	Quantity	Local currency	Foreign currency	Total
Electric car depot	Land grading & structures		11,667	5,000	16,667
	Tracks	11,000m	17,967	7,700	25,667
	Turnouts	60 sets	2,533	5,867	8,400
	Buildings		24,000	24,000	48,000
	Engineering		900	2,067	2,967
	Contingency		11,100	8,700	19,800
	Total		68,167	53,333	121,500
Malir branch	Improvement of station facilities	7,600m	4,722	1,945	6,667
	Engineering & Contingency		945	388	1,333
	Total		5,667	2,333	8,000

Table 9-2-(3)-1 Fund Plan by Categories and by Construction Phases ----- for Electric Installations

(In thousand rupees)

Categories of Work	Phase I				
	M.L.	KCR	M.C.B.	Electric car depot	Total
Sub-stations	110,566.7	40,000.0			150,566.7
Overhead trolley	100,633.3	39,100.0	8,600.0	5,866.7	154,200.0
Electric lighting & power	15,033.3	12,866.7	1,866.7	10,300.0	40,066.7
Signaling	35,566.7	33,033.3	4,100.0	12,166.7	84,866.7
Telecommunications	14,900.0	9,000.0	1,600.0	566.7	26,066.7
Sub-total	276,700.0	134,000.0	16,166.7	28,900.0	455,766.7
Engineerings					
Total					
Contingency					
GRAND TOTAL					

Table 9-2-(3)-2 Fund Plan by Categories and by Construction Phases for Electric Installations

(In thousand rupees)

Categories of Work	Phase II				
	M.L	KCR	M.C.B.	Electric car depot	Total
Sub-stations	28,300.0	13,333.3			41,633.3
Overhead trolley		47,333.3			47,333.3
Electric lighting & power		5,866.7			5,866.7
Signaling	23,233.3	14,833.3	266.7		38,333.3
Telecommunications	100.0	33.3			133.3
Sub-total	51,633.3	81,400.0	266.7		133,300.0
Engineerings					
Total					
Contingency					
GRAND TOTAL					

Table 9-2-(3)-3 <u>Fund Plan by Categories and by Construction Phases for Electric Installations</u>

(in thousand rupees)

Categories of Work	Phase III				
	M.L	KCR	M.C.B.	Electric car depot	Total
Sub-stations	138,866.7	53,333.3			192,200.0
Overhead trolley	100,633.3	86,433.3	8,600.0	5,866.7	201,533.3
Electric lighting & power	15,033.3	18,733.3	1,866.7	10,300.0	45,933.0
Signaling	58,800.0	47,866.7	4,366.7	12,166.7	123,200.0
Telecommunications	15,000.0	9,033.3	1,600.0	566.7	26,200.0
Sub-total	328,333.3	215,400.0	16,433.3	28,900.0	589,066.7
Engineerings					24,333.3
Total					613,400.0
Contingency					60,000.0
GRAND TOTAL					673,400.0

Table 9-3 Amount of Investment in Rolling Stock

(In thousand rupees)

Year	No. of additional rolling stock	Value
1981 - 82	168	448,000.0
1986 - 87	30	80,000.0
1991 - 92	102	272,000.0
1996 - 97	100	266,666.7
2001 - 02	50	133,333.3
2006 - 07	100	266,666.7
2011 - 12	50	133,333.3
Total	600	1,600,000.0

Notes: (1) All rolling-stock investment are based on foreign currency.

(2) The above values do not include number of rolling stock replaced after expiration of service life, and funding thereto.

Table 9-4 Total Amount of Investment

(In thousand rupees)

		Infrastructure	Electric car	Total
Alt. 1	Pakistan currency	931,033.3		931,033.3
	Foreign currency	1,523,000.0	1,600,000.0	3,123,000.0
	Total	2,454,033.0	1,600,000.0	4,054,033.3
Alt. 2	Pakistan currency	1,341,100.0		1,341,100.0
	Foreign currency	2,480,566.7	1,600,000.0	4,080,566.7
	Total	3,821,666.7	1,600,000.0	5,421,666.7

CHAPTER 10

Economic Evaluation

10-1. Object and Method

10-1-1 Cost-benefit analysis

In projects requiring an enormous sum for initial investment and a considerable period of time for the recovery of this investment as is the case with this Project, an essential point of a feasibility study is to judge whether the capital invested can produce a sufficiently large benefit or not through the execution of the project.

However, the judgement as to whether or not sufficient benefit can be produced is not easy since it depends on a number of indefinite future factors.

One of most essential questions is to determine the value produced by the services provided by the railway improved through the investment of an enormous sum: determination of the number of passengers availing themselves of such services and prices to be paid by these passengers.

One of analytical methods widely used so far for these questions is the cost-benefit analysis. This method has been used in this Section. In applying the cost-benefit analysis, every effort has been made particularly to avoid any overlapping calculation of a benefit susceptible to error and any mishandling of costs invested.

In this Section, cost and benefit have been determined on the basis of the fundamental concept of cost-benefit analysis. The effectiveness of this Project has been judged using three criteria: net benefit value, cost-benefit ratio and internal rate of return.

One of methods of economic evaluation in a broad sense is a financial analysis, which will be studied in the following section. The direct purpose of the financial analysis is to analyze an aspect of economic evaluation which is obviously different from that examined in this Section. However, the process and results of the financial analysis are indispensable to give a more detailed economic evaluation. It is therefore recommended to use the results of the study in this Section in combination with those in the following Section.

10-1-2 Assumptions

All economic evaluations mentioned above were made on the following assumptions:

(a) The period of time subject to the determination is 38 years including period of construction (1975 to 1981) and that of operation from 1982 to 2012 (the period 1982 to 1986 also being the construction period for the second phase of this Project).

(b) All prices are based on the price level as of 1974.

(c) Exchange rate between local and Japanese currencies is 1 rupee = 30 yen.

(d) Net benefit value and cost-benefit ratio are determined on the basis of two different discount rates: 6% and 12%.

(e) Base period for the value conversion in calculation of the total amount throughout the subject period is the year of 1982.

10-2. Forecast of Demand for Railway Transport

In the cost-benefit analysis based in principle on a comparison between cases with and without the execution of the Project, the forecast of demand for railway transport should also correspond to these two cases. In this connection, the following two types of passenger traffic volume must be estimated:

(a) Passenger traffic volume of the subject railway section in the case of non-execution of this Project.

(b) Increased passenger traffic volume of the subject railway section in the case of execution of this Project.

Results of these determinations are given in Table 10-1.

(See also Subchapter "Demand Forecast" of Chapter 2.)

Table 10-1 Passenger Traffic volume for Target Years (Daily Average)

Case	Unit	Year		
		1982	1987	2002
With execution of this Project	No. of passengers	150,000	314,200	752,000
	Passenger-kilometer	2,679,000	5,819,400	14,589,900
Without execution of this Project	No. of passengers	75,000	75,000	75,000
	Passenger-kilometer	1,287,000	1,287,000	1,287,000

10-3. Determination of Benefit

10-3-1 Types of benefit

Principal benefits which may be obtained through execution of this Project can be listed as follows:

(a) Passengers so far availing themselves of the existing railways will increase their traffic utility (such as saving travelling time consumed) by taking advantage of the improved railway services.

(b) Passengers giving up the utilization of buses, taxis or other means of transport and availing themselves of the improved railway services as well as those giving up the use or consumption of other goods or services and availing themselves of the railway will obtain increased utility from the improved services.

(c) Increase in number of passengers as mentioned in Item (b) above will permit the saving of investments in roads and other traffic facilities and means of transport. At the same time, the operation of such facilities, which would otherwise be inefficient due to traffic jams, will be largely improved.

(d) Provision of grade separated crossings and an automatic signaling system will relieve road traffic congestion and therefore improve the efficiency of operation of the road.

(e) Railway electrification and modernization of signaling, telecommunications and other facilities will result in improved efficiency of overall transportation, including the efficiency of operation of trains or rolling stock. This will permit savings to be made in resources (cost).

(f) Quadrupling of track for the main line and doubling of track for the K.C.R. are planned essentially to improve commuting facilities in the Karachi Metropolitan Area or urban traffic including the movement of general passengers. These measures will indirectly contribute to the efficient operation of long-distance passenger and freight trains departing from and arriving at the Metropolitan Area.

(g) In connection with Item (b), the spreading use of automobiles will be moderated. Environmental pollution resulting from automobile exhaust gases, which is attracting attention throughout the world, will therefore be reduced.

(h) Improved state of urban traffic expected from the introduction of modern electric cars and other various improvements will largely contribute, through the items mentioned above, to social and economic activities, and also become the pride of Karachi's citizens.

(i) Improvement of the existing railway line covered by this Project will form solid ground for the future electrification of the remaining main line section and construction of R/T spine and extensions considered in urban traffic planning.

Some of benefits listed above are intangible. In this study, only tangible benefits were quantitatively evaluated in such a manner that any overlapping calculation would be avoided. Such evaluation was carried out separately for the benefit enjoyed by users of the improved services and other types of benefit including savings in cost.

10-3-2 Determination of users' benefit

(1) Method of determination

The benefit to users taking advantage of the improved services has diverse aspects. In this study, however, only the saving in time was determined as general (see "note 1" at the end of this Chapter). This determination was simply made from the following equation on the basis of saving in time obtained by the use of improved services and average time value evaluated by users for one hour.

(Benefit of saving in time) = (Saving in time) x (Average time value)

(2) Average time value

Average users' time value was estimated by the income approach method. In this method, the time value is evaluated by estimating the sum of income gained per hour if the time saved is applied to an income-producing activity. For application of this method, therefore, the extent of employment opportunity should be taken into consideration. In other words, the employment rate of labor, users' earnings levels and other similar factors should be considered. In this study, however, workers' average earned hourly income was simply considered as the time value per commuter and a half thereof as the time value per common passenger. This can be given by the following equation.

(Average time value of one hour) = 0.9 x (average annual earned income per worker)/(52 weeks x 45 hours).

In this equation, coefficient 0.9 was obtained from
(0.8 x 1 + 0.2 x 0.5 = 0.9 by taking the ratio of commuters to all passengers as 0.8.

(3) Assumptions for evaluation

The increase in passenger traffic volume in the case in which this Project is executed consists of passenger traffic volume diverted from other means of transport and induced passenger volume generated by passengers giving up the use or consumption of other goods or services and availing themselves of the improved traffic services provided as a result of this Project. In this study, however, the whole increase in passenger traffic volume was assumed to ersult from the diverted passenger traffic volume. This is because the estimated passenger traffic volume consists substantially of commuters and consequently the induced passenger traffic volume is relatively small, and because the determination of induced passenger traffic volume is difficult because of the limitation of available data.

10-3-3 Results of evaluation

Benefit values of savings in time determined by the above-mentioned method for target years and total value for the entire subject period as calculated for the base year are shown in Table 10-2.

Table 10-2 Values of Saving in Time for Target Years and Total Value for the Entire Subject Period Calculated for the Base Year

(in thousand rupees)

		1982	1987	2002
Benefit values of saving in time	Passengers diverted from railways without improvement	9,311.5	9,947.7	9,947.7
	Passengers diverted from other means of transport	18,873.3	75,960.6	353,252.1
Total value for entire period	6%	2,972,267.0		
	12%	1,186,237.6		

10-4. Determination of Cost

10-4-1 Types of cost subject to determination

The value of savings in cost in the case of the execution of this Project and types of cost required for the cost-benefit analysis are as described below. In this study, these costs and values of saving were treated collectively.

(a) Annual cost required for recovery of the invested capital including investment cost for renewal after execution of this Project (cost generally known as the capital cost).

(b) Amount of saving in operating cost and capital cost for passenger traffic diverted from other modes by the execution of this Project.

(c) Amount of deduction from the initial investment when the investment for execution of this Project is also serviceable for other purposes, for example, relieving road traffic congestion.

The amount of saving in cost mentioned in Item (b) correspond to items of benefit (e) and (c) as listed in Paragraph 10-3-1 above, respectively. Item (c) listed above corresponds to benefits (d) and (f) as listed in Paragraph 10-3-1.

Benefits (d) and (f), in Paragraph 10-3-1 are given for road traffic or other railway transport as a result of the execution of this Project. In the present study, no direct measurement of these benefits was made, but a simple convenient treatment was made in Item (c) listed above.

10-4-2 Method of evaluation

The costs of initial investment and additional investment firstly needed for the determination of Item (a) of Paragraph 10-4-1 were determined by the investment fund program in Chapter 9.

The cost of Item (a) for capital recovery was determined on the basis of equal amortization by taking the average amortization period as 30 years for the infrastructure and 25 years for the rolling stock.

For Items (b), data for capital cost and operating cost for diverse means of transport contained in the "Final Report on Transport" of K.D.A. were referred to (see "note 2" at the end of this Chapter).

In the amount of saving in cost of Item (b), the saving in capital cost for railcars and road vehicles needed in the case of non-execution of this project was included. For determination of the saving in the cost for road vehicles, busses as the representative vehicle type, the average daily traveling distance (in kilometers) per bus and other data contained in the above-mentioned report were used.

Table 10-3 Sums of Investment by Years (Actual Sums) and Total Investment for Entire Period as Calculated for Base Year

(In thousand rupees)

Year		Investment for Alternative 1	Investment for Alternative 2
1975 - 76		1,833.3	1,833.3
1976 - 77		3,666.7	3,666.7
1977 - 78		107,066.7	395,600.0
1978 - 79		282,266.7	787,266.7
1979 - 80		352,066.7	857,066.7
1980 - 81		449,866.7	586,400.0
1981 - 82		251,633.3	240,366.7
1982 - 83		238,100.0	223,133.3
1983 - 84		306,333.3	287,600.0
1984 - 85		316,933.3	298,200.0
1985 - 86		126,266.7	122,533.3
1986 - 87		18,000.0	18,000.0
Total	6 %	2,628,548.0	4,342,704.0
	12 %	2,850,483.5	4,972,458.2

Table 10-4 Quantity of Required Electric Railcar by Years and Cumulative Amount of Funds

(In thousand rupees)

Year	Quantity of required railcar	Cumulative amount of funds
1980 - 81		
1981 - 82	168	448,000.0
1982 - 83		
1983 - 84		
1984 - 85		
1985 - 86		
1986 - 87	198	528,000.0
1987 - 88		
1988 - 89		
1989 - 90		
1990 - 91		
1991 - 92	300	800,000.0
1992 - 93		
1993 - 94		
1994 - 95		
1995 - 96		
1996 - 97	400	1,066,666.7
1997 - 98		
1998 - 99		
1999 - 2000		
2000 - 01		
2001 - 02	450	1,200,000.0
2002 - 03		
2003 - 04		
2004 - 05		
2005 - 06		
2006 - 07	550	1,466,666.7
2007 - 08		
2008 - 09		
2009 - 10		
2010 - 11		
2011 - 12	600	1,600,000.0
2012 - 13		

Unit cost of electric railcar is 2,666.7 thousand rupees.

10-4-3 Results of evaluation

(a) Cost of initial investment

Sums of investment by years and total investment for the entire period as calculated for the base year are given in Table 10-3.

(b) Cost of additional investment

In this Project, cost of additional investment is limited only to such funds as may be required for the addition of electric railcars. Quantity of required electric railcars by years and cumulative amount of funds are shown in Table 10-4.

(c) Capital cost for recovery of infrastructure investment

Table 10-5 gives annual capital cost calculated on the basis of amortization of the cost of investment (excluding the rolling stock) including renewal investments and total capital cost for the entire period as calculated for the base year (see note 3" at the end of this Chapter).

Table 10-5 Annual Capital Cost and Total Capital Cost for the Entire Period as Calculated for the Base Year

(in thousand rupees)

Item	Discount rate	6 %	12%
Annual cost	(1) Alternative 1	177,015.4	314,900.3
	(2) Alternative 2	283,962.3	549,320.3
Total cost	(1) Alternative 1	2,613,602.2	2,851,479.9
	(2) Alternative 2	4,192,654.9	4,974,196.1

(d) Capital cost of additional investment (electric railcar)

Capital cost by years calculated on the basis of amortization from Table 10-4 is shown in Table 10-6 together with the total capital cost for the entire period as calculated for the base year.

(e) Annual saving in operating cost after improvement and total saving for the entire period as calculated for the base year are given in Table 10-7.

Table 10-6 Capital Cost of Additional Investment (Electric railcar) and Total Amount for Entire Period as Calculated for the Base Year

Year	6 %	12 %
1980 - 81	35,045.6	57,120.0
1981 - 82	"	"
1982 - 83	"	"
1983 - 84	"	"
1984 - 85	"	"
1985 - 86	"	"
1986 - 87	41,303.7	67,320.0
1987 - 88	"	"
1988 - 89	"	"
1989 - 90	"	"
1990 - 91	"	"
1991 - 92	62,581.4	102,000.0
1992 - 93	"	"
1993 - 94	"	"
1994 - 95	"	"
1995 - 96	"	"
1996 - 97	83,441.8	134,000.0
1997 - 98	"	"
1998 - 99	"	"
1999 - 2000	"	"
2000 - 01	"	"
2001 - 02	93,872.1	153,000.0
2002 - 03	"	"
2003 - 04	"	"
2004 - 05	"	"
2005 - 06	"	"
2006 - 07	114,732.5	187,000.0
2007 - 08	"	"
2008 - 09	"	"
2009 - 10	"	"
2010 - 11	"	"
2011 - 12	125,162.7	204,000.0
2012 - 13	"	"
Total for Entire Period	952,091.1	826,116.2

Table 10-7 Annual Saving in Operating Cost and Total Amount for Entire Period as Calculated for Base Year

(in thousand Rupees)

Item \ Target year		1982	1987	2002
Annual saving		6,712.3	30,661.3	98,105.6
Total for Entire Period	6 %	812,949.6		
	12 %	340,213.7		

(f) Saving in number of road vehicles and railcars and saving in capital cost based on amortization of the investment required for such vehicles and railcars are given in Table 10-8-(1) and Table 10-8-(2).

Table 10-8-(1) Number of Saved Vehicles (Buses) and Cumulative Investment Amount therefor as well as Total Saving in Capital Cost for Entire Period as Calculated for Base Year

(In thousand Rupees)

Item \ Year		1982	1987	2002
Cumulative number of vehicles saved		277.3	954.6	3,215.2
Amount of cumulative investment for above		48,056.1	165;432.2	557,194.2
Saving in annul capital cost	6 %	7,738.8	26,640.5	89,728.3
	12%	9,665.9	33,274.7	112,072.9
Total saving for entire period	6 %	744,382.9		
	12 %	389,568.3		

Table 10-8-(2) Number of Railcars and Capital Cost to be Saved and Total Amount Assessed for Base Year

(In thousand rupees)

Item \ Year		1982	1987	2002
Number of railcars to be saved		64	64	64
Cumulative amount of fund for the above number of railcars		93,568	93,568	93,568
Annul capital cost to be saved	6%	7,341.9	7,341.9	7,341.9
	12%	11,274.0	11,274.0	11,274.0
Total saving for entire period	6%	108,401.9		
	12%	102,088.2		

(g) For the deduction from the initial amount of investment, examinations corresponding to two types of benefit as mentioned above (Items (d) and (f) in Paragraph 10-3-1) were made, but the cost relating to Item (f) was not precisely determined. Determination of the cost relating to Item (d) was carried out by assuming the share of expenses between road and railway as 6:4. As a result of this assumption, deductions of 897,288.1 and 1,273,629.4 thousand rupees were obtained for discount rates of 6 % and 12 % respectively. Capital cost based on amortization of the initial investment after such deduction is shown in Table 10-9 together with the total amount for the entire period as calculated for the base year. As already mentioned in Sub-chapter 9-3, any cost subject to deduction such as above mentioned is not included in the construction cost for Alternative 1. In this table, results obtained are given only for Alternative 2.

Table 10-9 Capital Cost after Deduction and Total Amount for Entire Period as Calculated for Base Year--Alternative 2

(in thousand rupees)

Item \ Discount rate	6 %	12 %
Annual amount	223,190.3	408,668.3
Total amount	3,295,366.8	3,700,566.7

10-5. Calculation of Criteria

On the basis of the above-mentioned data, calculations were made to judge whether the project can actually produce sufficient benefit for the national economy or not. Results of these calculations are given in Tables 10-10 and 10-11.

Table 10-10 Results of Calculation for Judgement for Alternative 1

(In thousand rupees)

Item \ Discount rate		6 %	12 %
Cost of initial investment		2,628,548.0	2,850,483.5
Benefit of saving in time		2,972,267.0	1,186,237.6
Benefit of saving in cost		1,665,734.4	831,870.2
Increase in capital cost caused by execution of this project	for infrastructure investment	2,613,602.2	2,351,479.9
	for additional investment	952,091.1	826,116.2
Net benefit value		1,072,308.1	Δ 1,659,488.3
Cost-benefit ratio (See Note 4)		141.03 %	41.80 %
Internal rate of return		7.66 %	

Table 10-11 Results of Calculation for Judgement for Alternative 2

(In thousand repees)

Item \ Discount Rate		6 %	12 %
Cost of initial investment		4,342,704.0	4,972,458.2
Benefit of saving in time		2,972,267.0	1,186,237.6
Benefit of saving in cost		1,665,734.4	831,870.2
Increase in Capital cost caused by execution of this project	for infrastructure investment	3,295,366.8	3,700,566.7
	for additional investment	952,091.1	826,116.2
Net benefit value		390,543.5	Δ 2,508,575.1
Cost benefit ratio		111.85 %	32.21 %
Internal rate of return		6.55 %	

10-6. Results of analysis

From the calculations for judgement, net benefit values of 1,072,308.1 and 390,543.5 thousand rupees were obtained at a discount rate of 6 % for Alternatives 1 and 2, respectively. At a discount rate of 12 %, both alternatives indicated negative net benefit value. For internal rate of return indicating the discount rate at which discounted net benefit for each year be zero as a total throughout the subject period, 7.66 % and 6.55 % were obtained for Alternatives 1 and 2, respectively. These results may not indicate that this Project gives marked advantage. As already mentioned, however, only the measurable "direct" benefits were determined in the present analysis. In addition, certain benefits included in the direct benefit category and obviously of considerable importance (such as benefit given to long-distance passenger and goods trains) were not determined. On the other hand, diverse "indirect" benefits or impacts not considered in the present analysis may possibly be of substantial importance.

Accordingly, the results of calculation for judgement as mentioned above can be considered to indicate that this Project is feasible. An overall economic evaluation will be described in detail after the financial analysis in the following section (See Paragraph 11-8 in Chapter 11.).

Note 1:

For inclusion of the benefit of time savings in the analysis, some economists are of the opinion that such benefits should be disregarded in economic evaluation of traffic projects in developing countries. This opinion seems to be based on the concept that the consumption of time is less important in those countries than in developed countries. For this Project, however, this concept is not acceptable for two reasons. First, economic activities in the Karachi Metropolitan Area are very extensive and will be developed into a modern organized form possibly in the near future. Second, the purpose of this project is to reduce the waste of time and fatigue now sustained by commuters due to increasing urban traffic congestion.

In view of these conditions, the benefit of time savings was included in the present analysis. The method of evaluation of such benefit was as described in the text. In anticipation of an increase in traveling time on highways resulting from traffic congestion expected in future, a progressive increase in time-saving benefit per unit railway passenger traffic volume was assumed.

Note 2:

Determination of operation cost is a most difficult problem. In the present analysis, the economic cost per unit passenger traffic volume published in the report of K.D.A. was used after modification taking price fluctuations into account. However, this cost per unit passenger traffic volume was not entirely fixed for the future, but divided into two portions as is normally done in Japan; one varying relative to the passenger traffic volume, and the other fixed and not varying relative to such volume. Such a division permits the reflection of the principle of mass production that the increase in production will, other things being equal, result in an increase in the rate of the increase in profit. This can be expressed by the following equation:

$$(\text{Operation cost})(t) = \alpha + \beta \cdot (\text{Traffic volume})(t)$$

In this equation, α and β are parameters and (t) is the year.

Note 3:

Strictly, the capital cost should be included for re overy of invested funds from the moment when facilities and machines covered by such funds have been made serviceable. However, this is very complicated. In the present analysis, a simple and easy method which may have no serious influence on results was adopted. Capital cost (K_Y) to be appropriated annually for a given amount of funds invested (I) was calculated by the amortization method given by the following equation. This method permits the omission of a residual value at the end of the subject period, which value would otherwise be required.

$$K_Y = \alpha \cdot I \frac{r(1+r)^n}{(1+r)^n - 1} + (1-\alpha) \cdot I \cdot i$$

wherein α = percentage of value of assets after deduction of residual value at the end of an assumed service life of assets;

r = discount rate;

n = assumed service life of assets in years.

Note 4:

As an index, the cost-benefit ratio varies with whether part of the cost saved, such as the saved portion of capital cost, is included in the denominator or the numerator. In this feasibility study, the cost-benefit ratio is derived from the following equation, using the parameters shown in Tables 10-10 and 10-11.

[Cost-benefit ratio] = {[Benefit of saving in time] +

[Benefit of saving in cost] - [Capital cost relating to additional investment in rolling stock]} ÷ [Capital cost relating to investment in infrastructure]

CHAPTER 11

Financial Analysis

11-1. Purpose of Financial Analysis

If a project requires a huge amount of funds as is the case with this Project, a heavy burden will have to be bore by the authorities concerned. There will be problems as to whether the cost for recovery of funds can be paid or not, whether the payment of such costs are compatible with the maintenance of profitable operation or not, and in general what financial measures should be taken for the execution of the Project. Financial analysis is a method for the study and analysis of these problems. However, conditions determining sound profitable operation, as a matter of fact are not always constant. Strictly speaking, so-called "sound profitable" actual operation depends on too many variable conditions, but in the present analysis, certain conditions are established to examine financial problems which could possibly arise from the execution of this Project by a really sound and profitable operator. This procedure will be particularly useful to Pakistan Railways, would-be executor of this Project, having a self-supporting accounting system.

11-2. Method of Analysis

In the present analysis, the principal factors listed below were considered and relations there between analyzed. In analyzing relations among factors, examination was made in particular for the financial conditions varied (1) when the passenger rate were raised or varied and (2) when the public investment to relieve the financial burden were put into effect and it's size of investment were varied. Factors are:

(a) Expected passenger traffic volume on the railway section covered by this Project after execution thereof.

(b) Passenger rate level.

(c) Expected revenue from the railway section covered by this project after execution thereof.

(d) Expected costs (capital cost and operating cost) after execution of this Project.

(e) Balance of revenue and expenditure as well as the profit resulting from Items (c) and (d).

(f) Size of investment.

(g) Amount of public funds invested.

11-3. Examination and Determination of Factors

Among items mentioned above, (a), (c) and (d), i.e. passenger traffic volume, revenue and costs were first determined. Results of these estimations are given in Tables 11-1 to 11-3. For taking account the capital cost, however, a method convenient to the present analysis was adopted so long as it would not affect the results seriously.

For determination of revenue and costs, the current cost level and passenger rate level of Pakistan Railways were taken into consideration. For passenger rate, the average charge rate of the Karachi Suburban Railways and national average charge rate of the Pakistan Railway and their variations were used. (Charge rates (A) and (B) mentioned later correspond to the former and the latter, respectively.)

In the present analysis, virtually no distinction between above mentioned Items (f) and (g) is required because an increase in public investment can be considered to correspond to the reduction of the size of investment.

The present analysis is limited only to Alternative 2 of plan of construction funds in which nothing has been deducted from the investment cost.

11-4. Analysis of Relations Among Factors

Fig. 11-1 shows the serial variations of revenue, operation cost and capital cost by year throughout the subject period.

This figure indicates the following facts:

(a) Revenue obtained by the current passenger rate level, i.e. charge rate (A) cannot cover the operation costs for the time being. Such revenue will exceed the operation cost from 2001, but the revenue remaining after covering the operating expences is too small to cover the capital cost. This is attributable partly to the abnormally low level of charge rate of Karachi Suburban Railway.

Table 11-1 Passenger Traffic Volume by Year on the Subject Railway Division (Daily Average)

	Passengers transported			Passenger-kilometers transported	
	Total	Commuters	Common Passenger	Total	Commuters
1982 - 83	150,000	120,000	30,000	2,679,000	2,143,200
1983 - 84	161,500	129,200	32,300	2,905,300	2,324,200
1984 - 85	173,900	139,100	34,800	3,150,700	2,520,600
1985 - 86	187,200	149,800	37,400	3,416,800	2,733,400
1986 - 87	201,600	161,300	40,300	3,705,500	2,964,400
1987 - 88	314,200	251,400	62,800	5,819,400	4,655,500
1988 - 89	333,000	266,400	66,600	6,187,100	4,949,700
1989 - 90	353,000	282,400	70,600	6,578,100	5,262,500
1990 - 91	374,100	299,300	74,800	6,993,800	5,595,000
1991 - 92	396,500	317,200	79,300	7,435,800	5,948,600
1992 - 93	420,300	336,200	84,100	7,905,600	6,324,500
1993 - 94	445,500	356,400	89,100	8,405,200	6,724,200
1994 - 95	472,200	377,800	94,400	8,936,300	7,149,000
1995 - 96	500,400	400,300	100,100	9,501,000	7,600,800
1996 - 97	530,400	424,300	106,100	10,101,400	8,081,100
1997 - 98	562,200	449,800	112,400	10,739,800	8,591,800
1998 - 99	595,900	476,700	119,200	11,418,400	9,134,700
1999 -2000	631,600	505,300	126,300	12,140,000	9,712,000
2000 - 01	669,400	535,500	133,900	12,907,100	10,325,700
2001 - 02	709,500	567,600	141,900	13,722,800	10,978,200
2002 - 03	752,000	601,600	150,400	14,589,900	11,671,900
2003 - 04	797,100	637,700	159,400	15,511,900	12,409,500
2004 - 05	844,800	675,800	169,000	16,492,100	13,193,700
2005 - 06	895,500	716,400	179,100	17,534,300	14,027,400
2006 - 07	949,100	759,300	189,800	18,642,300	14,913,800
2007 - 08	1,006,000	804,800	201,200	19,820,300	15,856,200
2008 - 09	1,066,200	853,000	213,200	21,072,800	16,858,200
2009 - 10	1,130,100	904,100	226,000	22,404,400	17,923,500
2010 - 11	1,197,800	958,200	239,600	23,820,200	19,056,200
2011 - 12	1,269,600	1,015,700	253,900	25,325,500	20,260,400
2012 - 13	1,345,600	1,076,500	269,100	26,925,800	21,540,600
Total of period	19,436,200	15,549,100	3,887,100	376,788,600	301,430,500

Table 11-2 Revenue by Year and Total Amount for Period as Calculated for the Base Year

1,000 Ruppee

Year		Charge rate - (A)	Charge rate - (B)	Charge rate - (C)	Charge rage - (D)
1982 - 83		9,054.8	27,966.0	55,932.0	111,864.0
1983 - 84		9,819.6	30,328.4	60,656.8	121,313.6
1984 - 85		10,649.1	32,890.2	65,780.0	131,560.0
1985 - 86		11,548.4	35,668.0	71,336.0	142,672.0
1986 - 87		12,524.2	38,681.7	77,363.4	154,726.8
1987 - 88		19,669.0	60,748.7	121,497.4	242,994.8
1988 - 89		20,911.8	64,587.1	129,174.2	258,348.4
1989 - 90		22,233.3	68,668.8	137,337.6	274,675.2
1990 - 91		23,638.3	73,008.3	146,016.6	292,033.2
1991 - 92		25,132.3	77,622.3	155,244.6	310,489.2
1992 - 93		26,720.1	82,526.6	165,053.2	330,106.4
1993 - 94		28,408.7	87,741.9	175,483.8	350,967.6
1994 - 95		30,203.8	93,286.0	186,572.0	373,144.0
1995 - 96		32,112.4	99,180.9	198,361.8	396,723.6
1996 - 97		34,141.7	105,448.5	210,897.0	421,794.0
1997 - 98		36,299.5	112,112.7	224,225.4	448,450.8
1998 - 99		38,593.1	119,196.7	238,393.4	476,786.8
1999 - 2000		41,032.0	126,729.5	253,459.0	506,918.0
2000 - 01		43,624.7	134,737.2	269,474.0	538,948.0
2001 - 02		46,381.7	143,252.3	286,504.6	573,009.2
2002 - 03		49,312.4	152,304.0	304,607.9	609,215.8
2003 - 04		52,428.7	161,928.7	323,857.4	647,714.8
2004 - 05		55,741.6	172,161.0	344,322.0	688,644.0
2005 - 06		59,264.2	183,040.6	366,081.2	732,162.0
2006 - 07		63,009.1	194,607.0	389.214.0	778,428.0
2007 - 08		66,990.6	206,904.1	413,808.2	827,616.4
2008 - 09		71,224.0	219,979.0	439,958.0	879,916.0
2009 - 10		75,724.6	233,879.5	467,759.0	935,518.0
2010 - 11		80,510.0	248,659.0	497,318.0	994,636.0
2011 - 12		85,597.7	264,372.9	528,745.8	1,057,491.6
2012 - 13		91,006.5	281,078.4	562,156.8	1,124,313.6
Total	6%	444,292.2	1,372.221.7	2,744,443.4	5,488,886.8
	8%	333,712.6	1,030,687.4	2,061,374.8	4,122,749.6
	12%	205,680.0	635,252.1	1,270,504.2	2,541,008.4

Rate (A) = Average charge rate estimated for the Karachi Suburban Railway of Pakistan Railways (= 0.00926 rupees/passenger-kilometer).
Rate (B) = Average charge rate estimated for the Pakistan Railways (=0.0286 rupees/passenger-kilometer).
Rate (C) = Rate (B) x 2.
Rate (D) = Rate (C) x 2.
Rate (E) = Rate (D) x 2, which is used in other part of this Chapter.

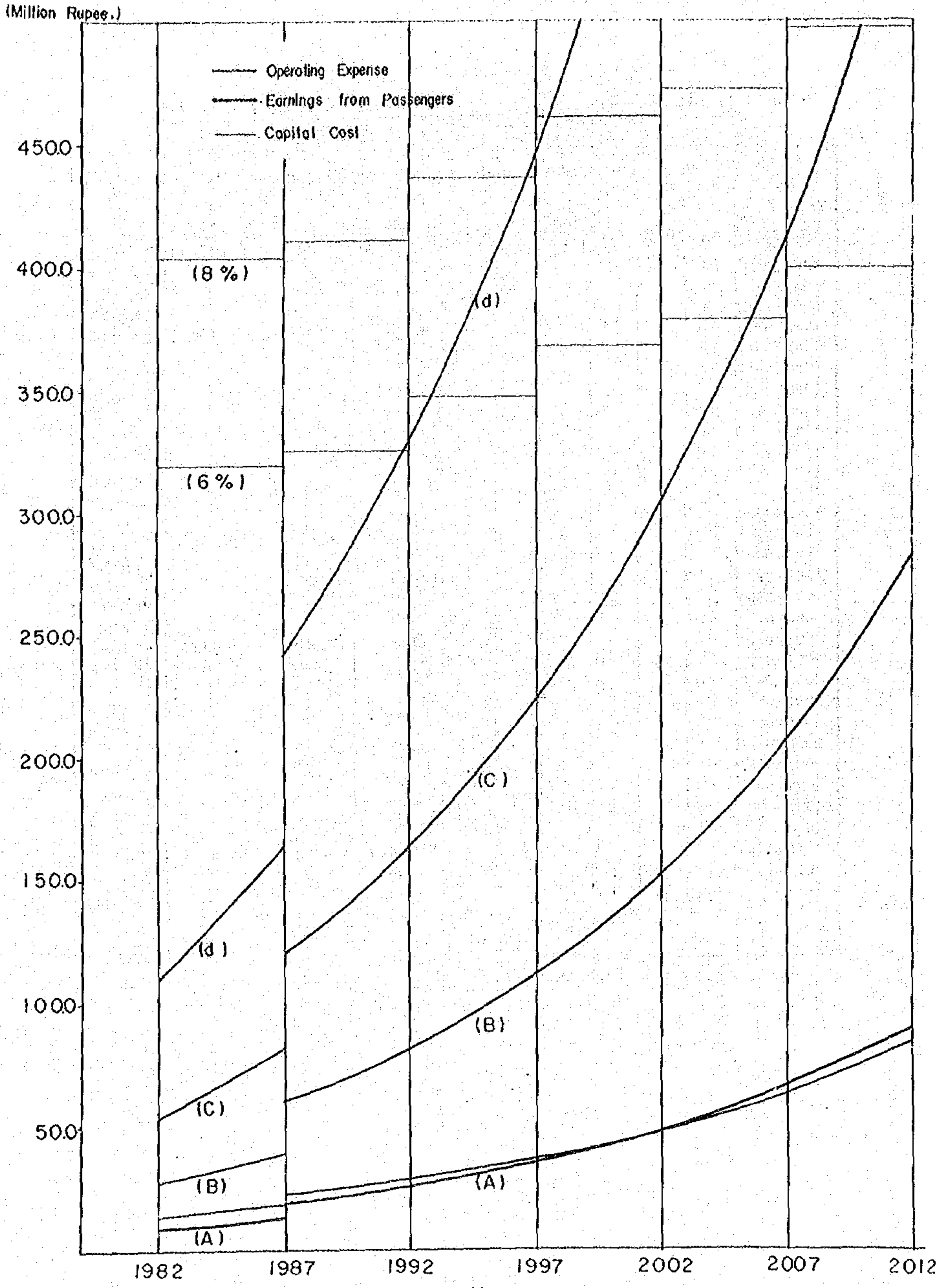
Table 11-3 Costs by Year and Total Amount for Period as Calculated for Base Year

(In thousand rupees)

Year \ Discount rate \ Cost	Capital cost for initial investment			Capital cost for additional investment			Operation cost
	6%	8%	12%	6%	8%	12%	
1982 - 83	297,634.6	373,413.6	551,159.9	(35,045.6)	(41,968.1)	(57,120.0)	14,530.7
1983 - 84							15,179.4
1984 - 85							15,882.8
1985 - 86							16,645.5
1986 - 87				41,303.7	49,462.4	67,320.0	17,473.0
1987 - 88							23,532.2
1988 - 89							24,586.2
1989 - 90							25,706.9
1990 - 91							26,898.4
1991 - 92				62,581.4	74,943.0	102,000.0	28,165.4
1992 - 93							29,512.0
1993 - 94							30,944.0
1994 - 95							32,466.3
1995 - 96							34,084.9
1996 - 97				83,441.8	99,924.0	134,000.0	35,805.9
1997 - 98							37,635.8
1998 - 99							39,580.8
1999 - 2000							41,649.2
2000 - 01							43,848.0
2001 - 02				93,892.1	112,414.5	153,000.0	46,186.1
2002 - 03							48,671.5
2003 - 04							51,314.3
2004 - 05							54,123.8
2005 - 06							57,111.2
2006 - 07				114,732.5	139,395.5	187,000.0	60,287.1
2007 - 08							63,663.6
2008 - 09							67,253.7
2009 - 10							71,070.5
2010 - 11							75,128.7
2011 - 12				125,162.7	149,986.0	204,000.0	79,443.4
2012 - 13	↓	↓	↓	↓	↓	↓	84,030.4
Total amount 6%	4,389,343.1	–	–	952,091.1	–	–	477,950.8
Total amount 8%	–	4,573,512.1	–	–	897,319.8	–	366,994.7
Total amount 12%	–	–	4,989,015.1	–	–	826,116.2	236,472.0

( ) means the cost to be paid in 1981 - 1982

Fig. 11-1 Relation Between Earnings and Expenses



(b) Cost for recovery of funds, namely the capital cost, is remarkably high relative to operating cost and revenue. Even if passenger rate are set to charge rate (B) (See Table 10-2), the annual capital cost based on the amortization cannot be covered in full until 2012. This is mainly because the huge amount of invested funds (initial investment) expands the capital cost to be appropriated annually. Accordingly, if a sufficient public investment is applied to part of such funds, the burden of capital cost can be relieved correspondingly. As a result, profitable operation can be made possible without raising the charge rate abnormally.

These two points are analyzed in detail in the following.

11-5. Analysis of the Financial Conditions in which Passenger rate Changed

Admittedly, passenger rate cannot be raised unreasonably. If passenger rate are raised in disregard of users' economic conditions and the value of the services, users will give up the use of the services in question. Without users, expensive transport facilities will be worthless. In this analysis, the case in which only passenger rate change, other conditions being equal, is assumed for the purpose of simulation. In this case, the analysis is made to determine how many times the current carriage charge level makes this Project financially feasible, that is, what level of carriage charges enables the operating body concerned to maintain sound operation. Results of analysis are given in Fig. 11-2.

This figure represents the tendency of changes in the benefit value and break-even point with the carriage charge level changing at a discount rate of 6 %. As is clear from this figure, the net benefit at a discount rate of 6 % cannot be produced until the passenger rate level has exceeded a charge rate of (D).

11-6. Analysis of the Financial Conditions in which Public Investment is put into Effect

An analysis similar to that for the case in which the passenger rate are changed as described above was made for the case in which the amount of public investment was changed. Results obtained are given in Fig. 11-3. All results are for a passenger rate level set at rate (C).

Fig. 11-2 Relation between Rate of Fare and Pure Benefit

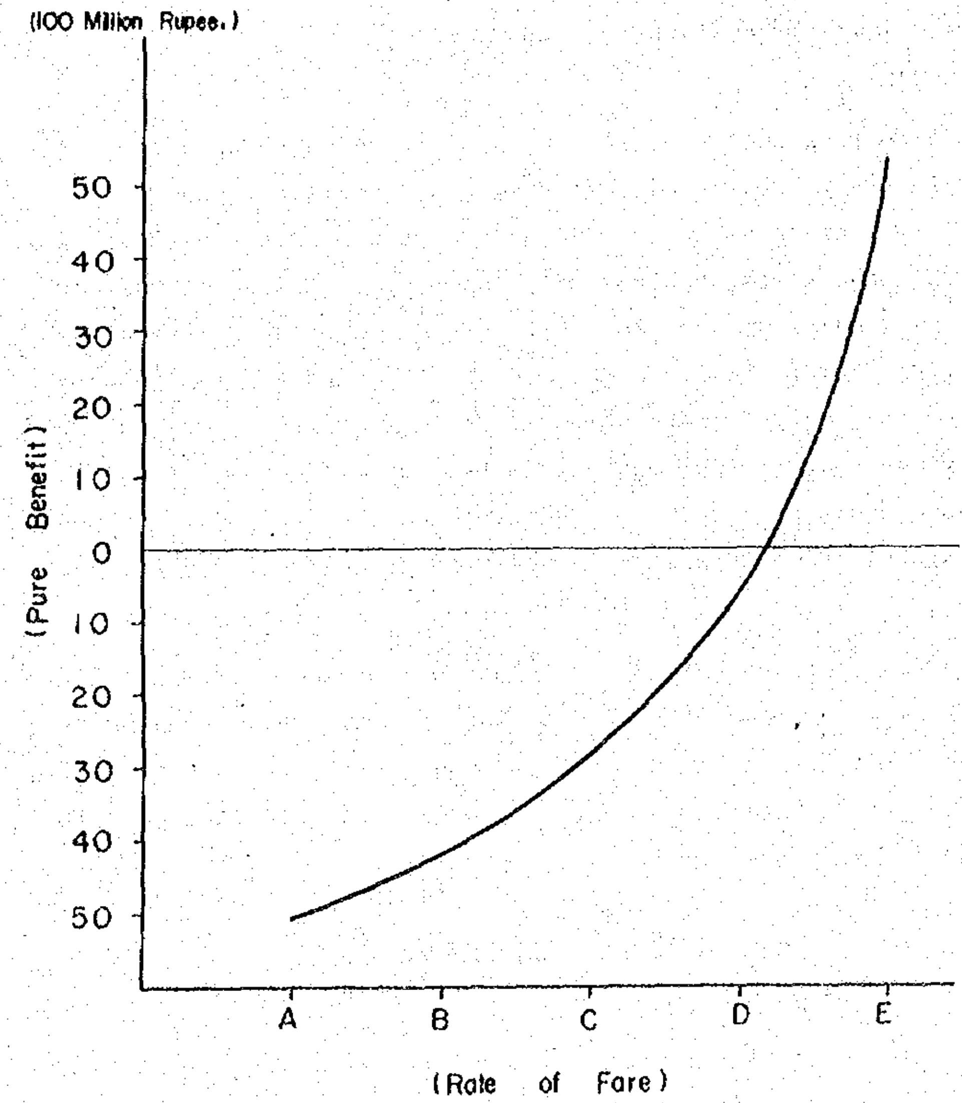
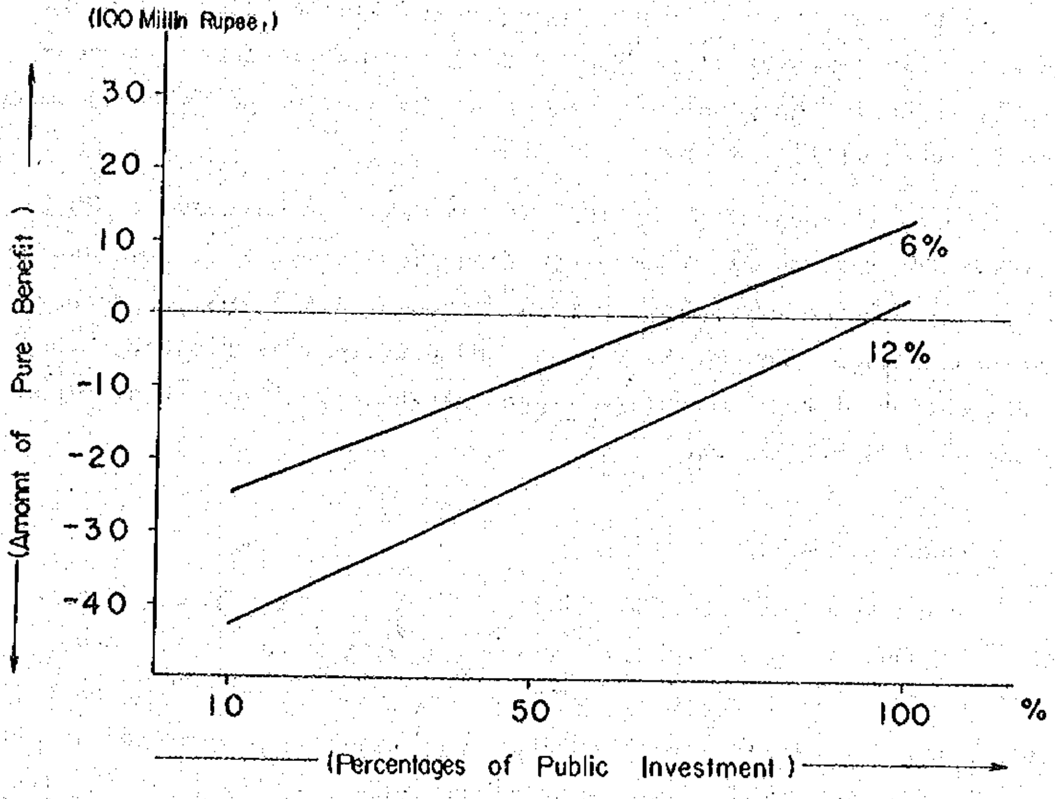


Fig. 11-3 Relation between Public Investment And Pure Benefit



As is clear from the figure, the net benefit cannot be produced at a discount rate of 6 % until the proportion of public investment in the whole initial investment has exceeded about 70 % and at a discount rate of 12 % until that proportion has exceeded about 95 %.

Passenger rate, proportion of public investment and net benefit can be correlated to each other as shown in Fig. 11-4.

11-7. Evaluation of Results of Financial Analysis

Results of the financial analysis described above indicate that the present project is hardly profitable so long as it is required to maintain profitable operation as in private enterprises.

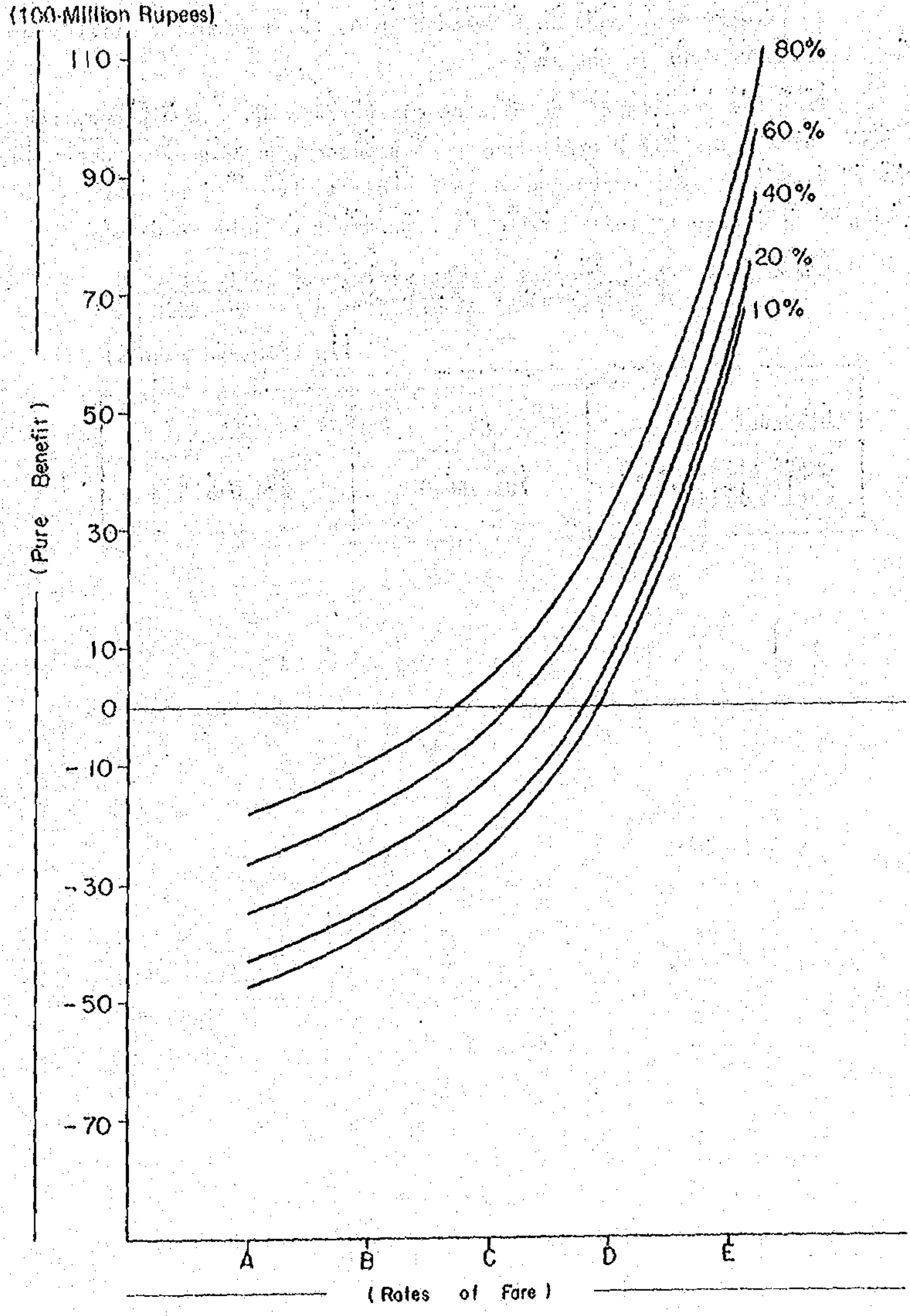
In the performance of profitable operation of this Project is intended, fully covering costs by operating revenue in future, a considerable raise in the passenger rate or investment of an enormous amount of public funds will be required.

The operating ratio for 1973 of the Pakistan Railways is 78.2. Net profit for the same year after appropriation of interest and depreciation is only 530 rupees against a total revenue of 974,703,000 rupees. If Pakistan Railway intends to execute and perform this Project through the application of the current carriage charge level, the annual financial burden will not be small.

11-8. Economic Evaluation

This Project relates to urban traffic. In any urban traffic project, whether it is a highway traffic project, a railway or other traffic project, sound operation will be very difficult so long as profitable operation similar to that adopted by private enterprises in taken as a precondition. This is because a huge amount of funds is required for the construction of traffic facilities in an urban area, whether such facilities are railway facilities or highway facilities. This Project contemplates the modernization of the existing railway facilities. If a highway is to be constructed as a substitute, the amount of funds required therefore may exceed that for the construction of the infrastructures in this Project. In this case, however, the capital cost is assumed equal for both amounts of funds. On this assumption, the operat-

Fig. 11-4 Interrelation among Rate of Fare, Public Fund and Net Revenue



ing cost saving obtained by this Project is calculated in comparison with that by providing highway transport. The results calculation are given in Table 11-4.

As already mentioned in Paragraph 10-6, the economic benefit produced by this Project is not small.

From the results of the diverse evaluations described above, the economic effect of this Project can be considered well worthy of appreciation as a whole. For execution of this Project, however, positive financial aid, in particular, from the Government will be required.

Table 11-4 Total Operating Cost Saving for Entire Period by this Project as Calculated for the Base Year

(In thousand rupees)

Discount rate	6%	12%
Total saving for entire period	782,750.0	324,023.3

PART 3 R T S

CHAPTER 12

Rapid Transit System

12-1. Rapid Transit System and its Scope

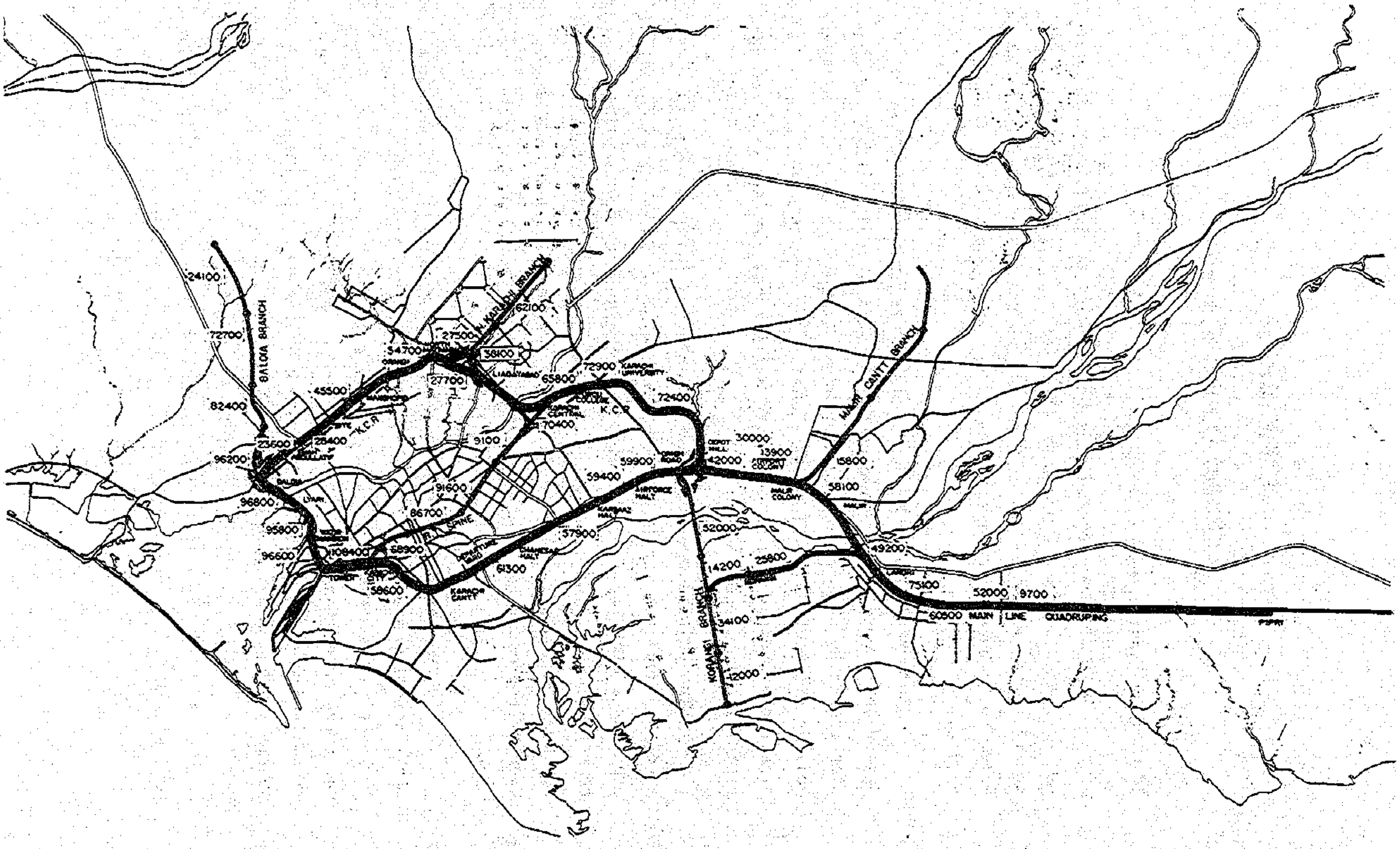
With the cooperation of a United Nations study team in 1971, the KDA drafted a 1985 - 2000 master plan for the Karachi Metropolitan Area. In this plan, emphasis was laid on the future urban traffic of the city which sould be handled chiefly by buses and tramcars, but railways should follow.

However, pressed by the need to re-examine the future traffic demand and capacity with respect to increasing road traffic and congestion caused by the population increasing sharply in the Karachi Metropolitan Area, the RTS Cell was established within the PR in June, 1974 to vigorously promote the construction of four new railway lines forming a rapid transit system.

The objective of this preliminary feasibility study is to investigate the scope (outline) of the construction of the four new lines in accordance with the urban development plan and the land utilization plan from the master plan, i.e. a rapid transit spine (R/T spine) and three other extensions, in connection with the electrification and modernization of the existing lines requested heretofore by the Pakistani Government.

In the above context, the R/T spine means the new line which will link Karachi Central Station on the KCR with Karachi City Station or a new station (provisionally called "Tower Station") on the main line, and the three extensions mean the lines one of which is the North Karachi Branch and will be extended from North Nazimabad Station and Liaquatabad Station on the KCR line to the northeast; a second line is the Baldia Branch and will be extended from Baldia Station on the KCR line to the north; a third line is the Korangi Branch and will be extended separately from Drigh Road Station on the main line to the south via Korangi Station, the existing terminal station of the Korangi Branch. (Fig. 12-1)

Fig. 12-1 Estimated Daily Passengers on Rail Rapid Transit in 1985



12-2. KDA's Master Plan and Rapid Transit System

12-2-1 The Master Plan and Traffic

The project covered by the KDA master plan consisted of four Phases; Phase 1 related mainly to the establishment of the framework and the subsequent Phases, 2, 3 and 4, were carried out in three cycles. Through the first cycle, the future growth potential of Karachi was investigated, in it the two alternatives for long-term development policy, DIP and CIP (see paragraph 2-1-2), were set for the years 1985 and 2000. The Pakistani Government selected, as a desirable subject for the succeed ing work, one of the policies from its first cycle.

The second cycle was aimed at the promotion of further developing a special policy for 1985.

The third cycle established the methods of developing in detail and finishing the selected plans.

However, the second and third cycles brought about some problems in the sphere of traffic analysis. For this reason, the first cycle was adopted with respect to traffic.

The 1985's three transport plans related to the suburban areas of Karachi were as described already in paragraph 3-1. In the plans, of the public means of transport, in principle public buses were called upon to play an important role until 1985, and for this purpose, the plan emphasized that 3,300 or more buses should be put into service until 1985.

With regard to railways, the plan claimed that the existing KCR and main lines should have their facilities improved so as to increase traffic handling capacity and enhance the degree of utilization of these railways, and thereby cope with the increasing traffic demand. For this purpose, the plan insisted on the necessity of 320 coach vehicles by 1985.

12-2-2 Land Utilization Plan and the Relationship Thereto

The KDA concluded in its "Final Report on Transportation" that traffic demand and land utilization should be as stated below. (page 64)

Assessment of travel patterns rearranged a series of land utilization schemes enabling a decrease in the overall demand for travel. This rearrangement included the following measures:

1. Higher levels of employment in the northern and north-eastern area of the city. (Dissipation of industrial areas.)
2. High population, particularly high-income, in or near the central area. (High-density population to be attained by re-development of the city.)
3. Higher population to the south or south-east of the central area. (Enhancement of the degree of utilization of the main line.)
4. Development to the west of the city (Mauripur or beyond). (Enhancement of the degree of utilization of the KCR line.)

Note: In the above-mentioned items, the comments of this study team are in parentheses.

These measures would reduce the traffic flow moving from the north and northeast corridors to the highly concentrated employment area in the center of the city. These corridors constitute future problem areas in the sphere of the urban traffic system. Such a traffic flow would have to pass through areas already developed to a considerably high level making it difficult to increase the existing road capacity or areas where it would be very expensive to permit the increase of traffic flow.

In connection with this, the KDA Final Report made the following comments: (page 7) There were some aspects in which desirable changes in the land use and travel patterns could not be achieved, because of the limitations imposed by existing development patterns. In these cases, any measures which were available were taken to reduce the undersirable effects, but those remaining had to be accepted as long-term city characteristics.

The most important presentation in the Final Report relates to the high-level employment in the central area of the city. This means that even though the future employment concentration would be restricted to the level of the present time, it may bring about an extremely high radial movement (commuter traffic), the need for large-capacity roads and the addition to and improvement of public transit lines running from suburban populated areas to the center of the city.

Namely, even while measures to reduce commuter traffic flowing into the highly concentrated employment area in the center of the city would be taken, a strong demand for traffic would still remain unsolved in the future. In this respect this study team understands that the provision of a spine will still have to be considered.

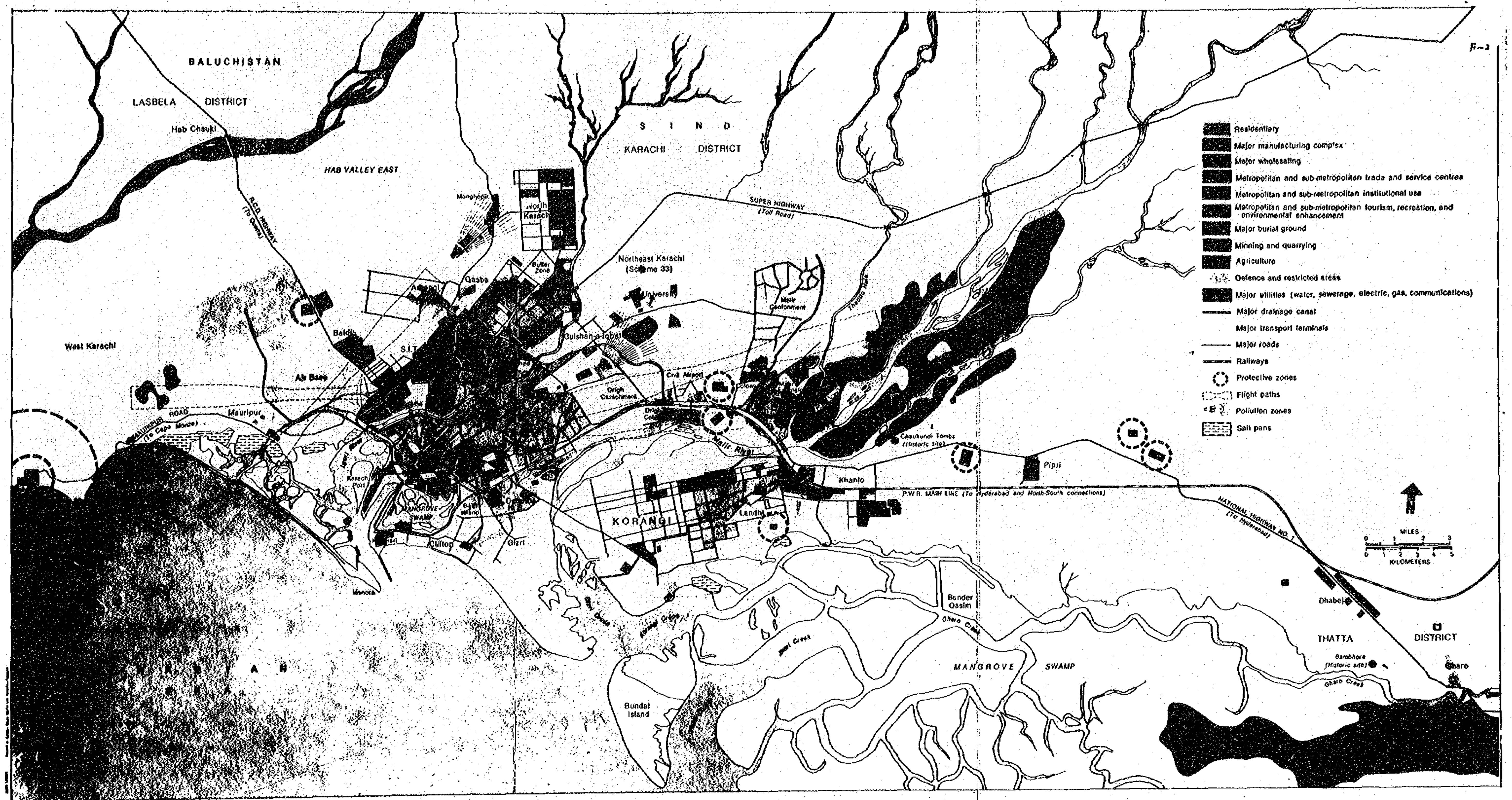
Brief descriptions of the regions connected by the three extensions are given hereunder.

North Karachi would still constitute for the time being the most problematic area in all the Karachi Metropolitan Area: a vast area designated as a housing area exists in North Karachi and this has long been underpopulated. This area should be utilized so as not to waste investments which have been made and remain unused.

Meanwhile, South part which forms a large triangular area and has long been proposed to be the center of the community is being developed mainly for use as a housing area. This study team saw many apartment houses under construction when it made field investigations.

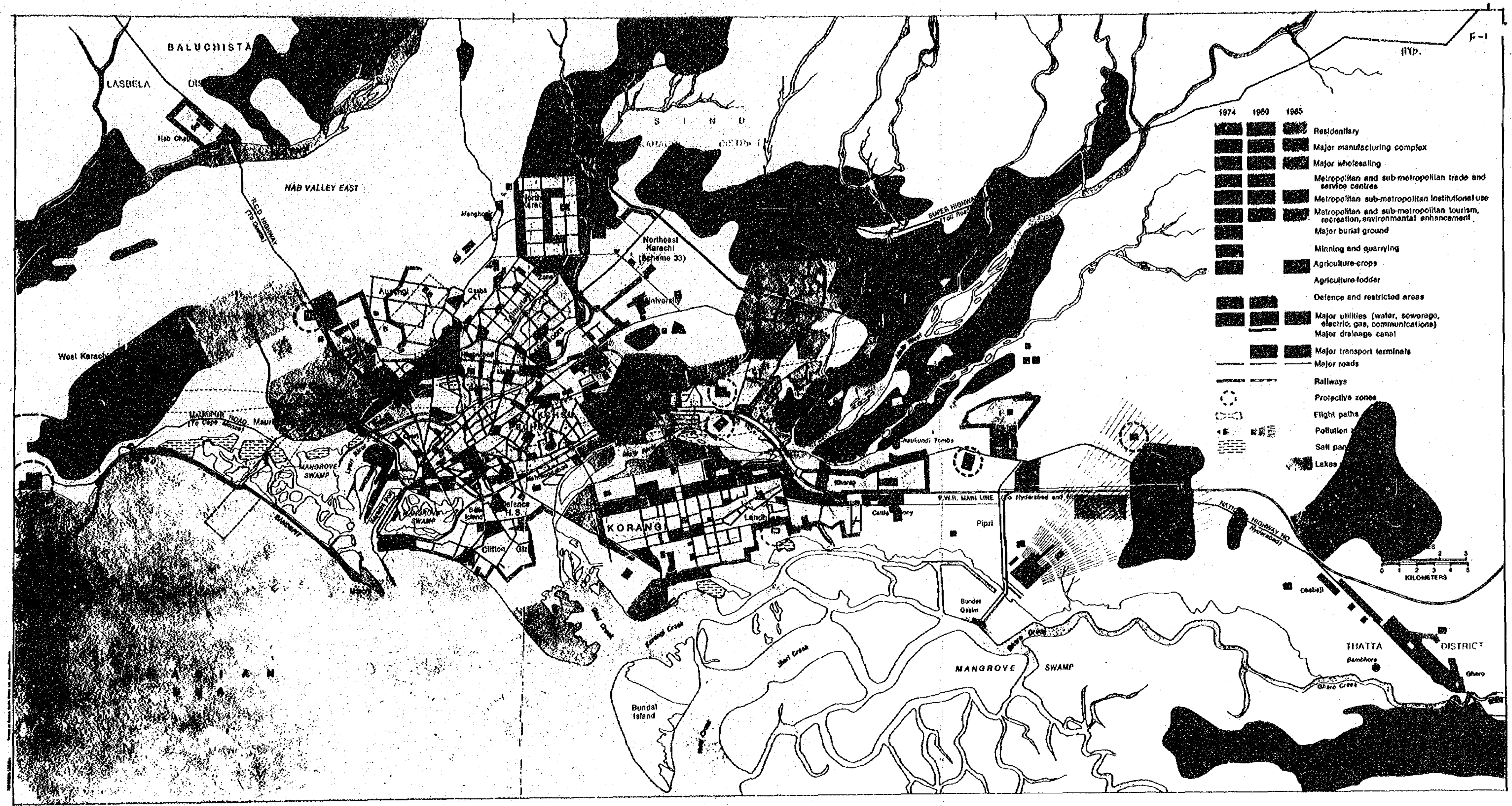
The dwelling area from Baldia to Aurangi is expected to become an attractive area for those moving there from other areas. The high-level increase of population predicted in the 1974 - 1980 period would make necessary that the KDA take action in preparations for this. Experience gained from urban development plans now under way may be useful in this respect.

Korangi is expected to become an area with an increasing population in the 1974 - 1985 period. In Phase 1 which will continue until 1980, the necessity will be to start suitable industrial development. The major developments should be aimed at achieving the development of industries of the proper scale. This should be the premise for the alternatives proposed by the KDA master plan as to whether they can be carried out successfully. (Figs. 12-2, 12-3)



KARACHI METROPOLITAN AREA LAND USE • 1974

Fig 12 - 3



KARACHI METROPOLITAN AREA LAND USE • 1980 AND 1985

12-3. Relationship between Rapid Transit System and Mass Rapid Transit System

This study team proposed in Chapter 3 of this report the concept of the mass rapid transit system by means of railway. This obviously takes into account the rapid transit system requested by the Pakistani Government. Therefore, the team is of the understanding that upon proceeding with establishing the rapid transit system in the future, the electrification and modernization of the existing lines should be executed as a first project, which should follow the execution of the rapid transit system, namely the R/T spine and the three extensions, as a second project. This results from the reasons that, since the rapid transit system is planned to link with, in future, the existing KCR line and the main line, these lines must have had their traffic capacities increased by electrification and modernization as well as all necessary preparations must have been made to provide passengers with quality traffic service.

Assuming that the provision of the rapid transit system preceded the existing KCR and main lines, it would undoubtedly help ease the traffic congestion in certain limited sections, but in view of the future urban development plan, the land utilization plan and the plant layout plan which were proposed in the KDA master plan, it is estimated that the traffic flow of passengers would be extensive rather than moving in certain limited sections.

Therefore, the precedence of the rapid transit system over other requirements may uselessly aggravate not only the congestion of passengers at junction stations, but also snarl up urban traffic in the central area of the city which in turn causes passenger flow to further congested, thus moving backwards from the objective of the rapid transit system. With regard to the spine, etc., the electrification and modernization of the existing lines under Project 1 would be predicted to overlap, in part, those under Project 2.

12-4. Traffic Demand Forecast

Concerning the railway traffic volume at the time of completion of the above-mentioned four new lines, the KDA and the RTS-Cell made the forecast shown in the year 1985 columns of Tables 2-3 and 2-4, including that of the year 2000. According to this forecast, the number of passengers in 1985 is predicted to increase by 6.5 times over that in 1971, and passenger-miles in 1985 will be 7 times that in 1971. In 2000, the number of passengers will become 24 times the 1971 figure and passenger-miles will increase by 27 times.

Whereas, the electrification plan of the existing lines proposed by this study team has forecasted that number of passengers in 2002 would be up to 10 times over 1974 and passenger-miles up by 11 times.

For 2000, as shown in Fig. 12-4, the Northeast Karachi Branch, the second loop line, which will link the Malir Cantonment Branch with Karachi Central Station and the Western Karachi Branch planned to be extended to the west from Baldia are included in the plan.

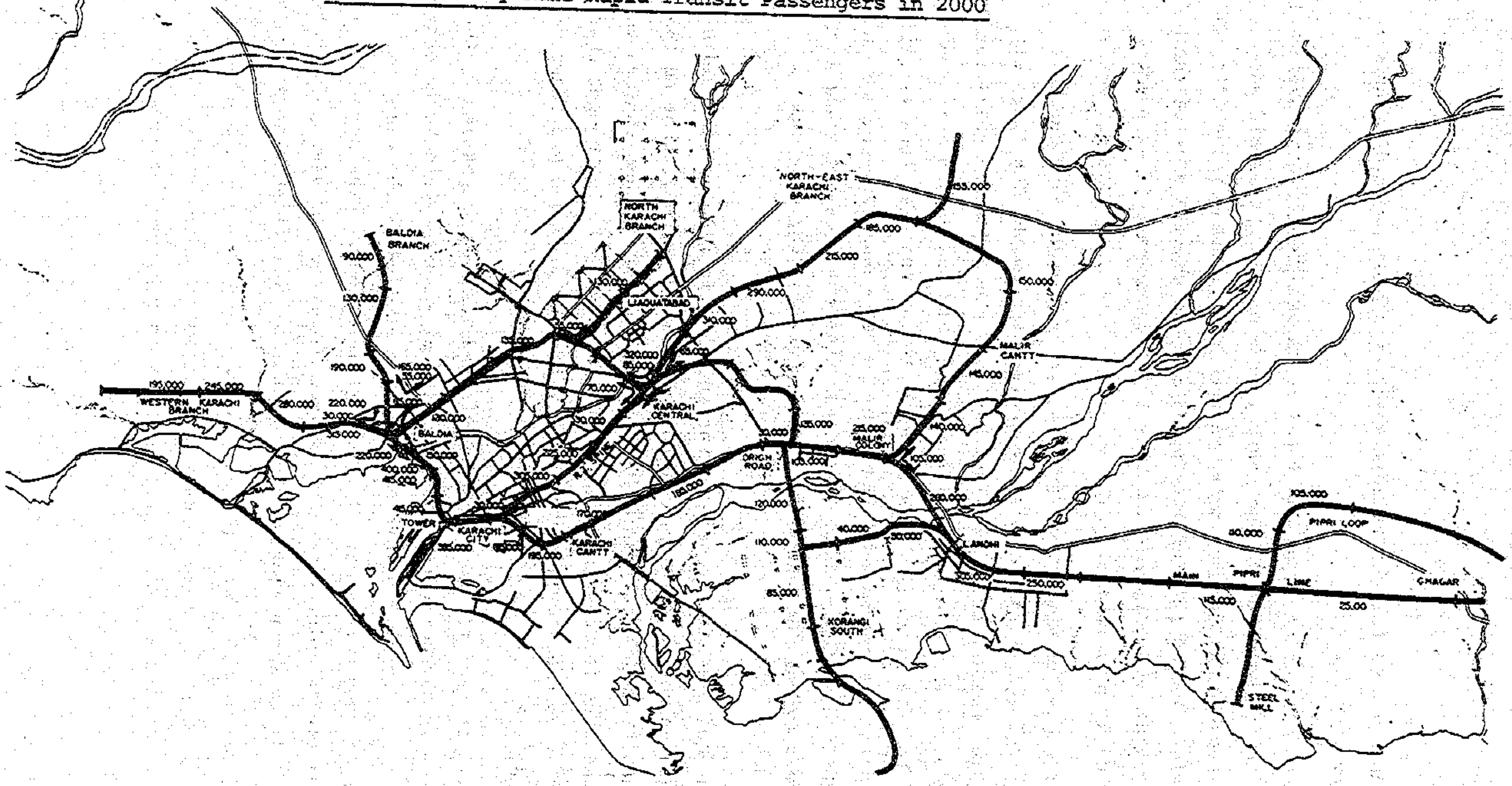
(Fig. 12-4)

The plan has defined that the four new lines should be constructed completely between 1987 and 2000; the combined gross traffic volume of all modes of traffic in 2000 should remain the same as that shown in Tables 2-3 and 2-4. Forecasting the traffic volume by railway on the three premises that the four new lines are completed after 1987 but before 2000, that the overall traffic volume by all the traffic modes in 2000 remain unchanged in the figures shown on Tables 2-3 and 2-4, and that the shares of the railways against the above-mentioned overall traffic volume remain unshifted both in 1985 and 2000, the number of passengers will increase by 17 times over 1974, or 19 times in terms of passenger-miles.

12-5. The Necessity for Rapid Transit System

The preceding paragraph has described the overall forecast of traffic demand. This forecast is based on the premise that the mass rapid transit system in Project 1 (electrification and modernization of existing lines) shall have been completed before 1987 and Project 2 (spine and 3 extensions)namely the construction of the mass rapid transit system, before 2000. With a view to the gross traffic demand and the share of traffic to be borne by the railway, a traffic volume of this level is arrived at. Reversely, it may be thought that the forecast

Fig. 12-4 Estimated Daily Rail Rapid Transit Passengers in 2000



demonstrates the need for the establishment of the mass rapid transit system as Project 2.

To be more precise, as described in paragraph 12-2, the degree of concentration of employees in the central area of the city would not decrease so long as businesses exist in the central area of the city, if so, the traffic inside the KCR line bound for the central area of the city would necessarily increase. This traffic increase is at present handled by means of road traffic.

After the 1st mass rapid transit system project has been completed, part of this traffic increase would shift to the KCR lines with higher running speeds, but a considerable part thereof would still remain on the roads and it could be considered that this would form a reason for passengers to take advantage of a spine. In the KDA plan, the traffic flow on a spine was estimated to be about 90,000 passengers per day in 1985. (This study team hereby recommends that the figure for the year 1985 proposed by the KDA should be taken as one for the year 1987 or later.)

The KDA plan also forecast that the traffic flow on the Baldia Branch would amount to more than 70,000 passengers per day, that on the North Karachi Branch more than 60,000 passengers per day and that on the Korangi Branch at least 40,000 passengers per day. It is thought that these traffic volumes imply the necessity for the proposed new lines to be provided.

With respect to the situation of road traffic congestion at the central area of Karachi City, the provision of a spine would be necessary, because the full traffic volume could not be handled by the existing roads even if they were improved to a certain extent. The necessity for the provision of a spine can be recognized also from the view points of energy efficiency and pollution such as that by automobile exhaust gases.

Concerning the three extensions, the concept that part of the extensions should use tramcars must be abandoned, but electric cars should be used with a view to mass rapid transit system requirements in the future.

12-6. Construction of Rapid Transit System

12-6-1 Structure of System

(1) Spine

As a 2-mile section of the spine closer to Karachi City is in an urban area, either an elevated track or subway should be selected to form this section. If an elevated track is to be selected, the following problems will be encountered.

1) The construction of an elevated track over roads will decrease the effective width of the roads.

2) Elevated tracks will cause adverse effects such as noise and vibrations upon the community and spoil the appearance of the streets more than a subway would.

3) Utilization of land surface will be obstructed. Judging from the circumstances of the place, these problems cannot be considered to be acceptable by the public, so this section should be a subway even if its construction cost will be high.

Generally, the construction of a subway at a depth close to the ground surface is less expensive than one at a greater depth. In the case of the former, evacuation if a disaster occurs is easy and it is more expedient to passengers. With regard to the structure, the adoption of box section is preferred as a whole though this depends on the method of construction, because frames of smaller cross-sections are better. The internal dimensions of the frame should be determined through overall examination of the types of electric cars relating to it. In addition, concerning the structural system, the provision of ventilation and cooling systems should be studied taking into consideration the temperature (45°C) in midsummer. Intrusion of passengers into the trackway, as seen on PR at present, will be a problem to be solved. As a conclusion, these problems should be taken into account when determining types and sizes of stations and mechanical facilities and ceiling heights.

On the other hand, a section of about 4 miles closer to Karachi Central Station consists mainly of housing and industrial areas where not many buildings exist at present. However, it is predicted that this area will be densely populated with many houses, and the number of factories will increase into this area. Based on this concept, the railways and roads should be grade separated. In this case, there are two methods by which the railways can be dealt with; elevated and underground railways. This area, however, should be provided with elevated track because it is not an urban area, and elevated track has more benefits, considering the cost of construction, etc. (Fig. 12-5)

(2) Extensions

1) North Karachi Branch

Topographically, this area is flat land with a marginally high elevation because it is located away from the coast. The environs of the line are largely housing areas. Therefore, the extension line should run through cutting and should be grade separated from roads, but running under the latter.

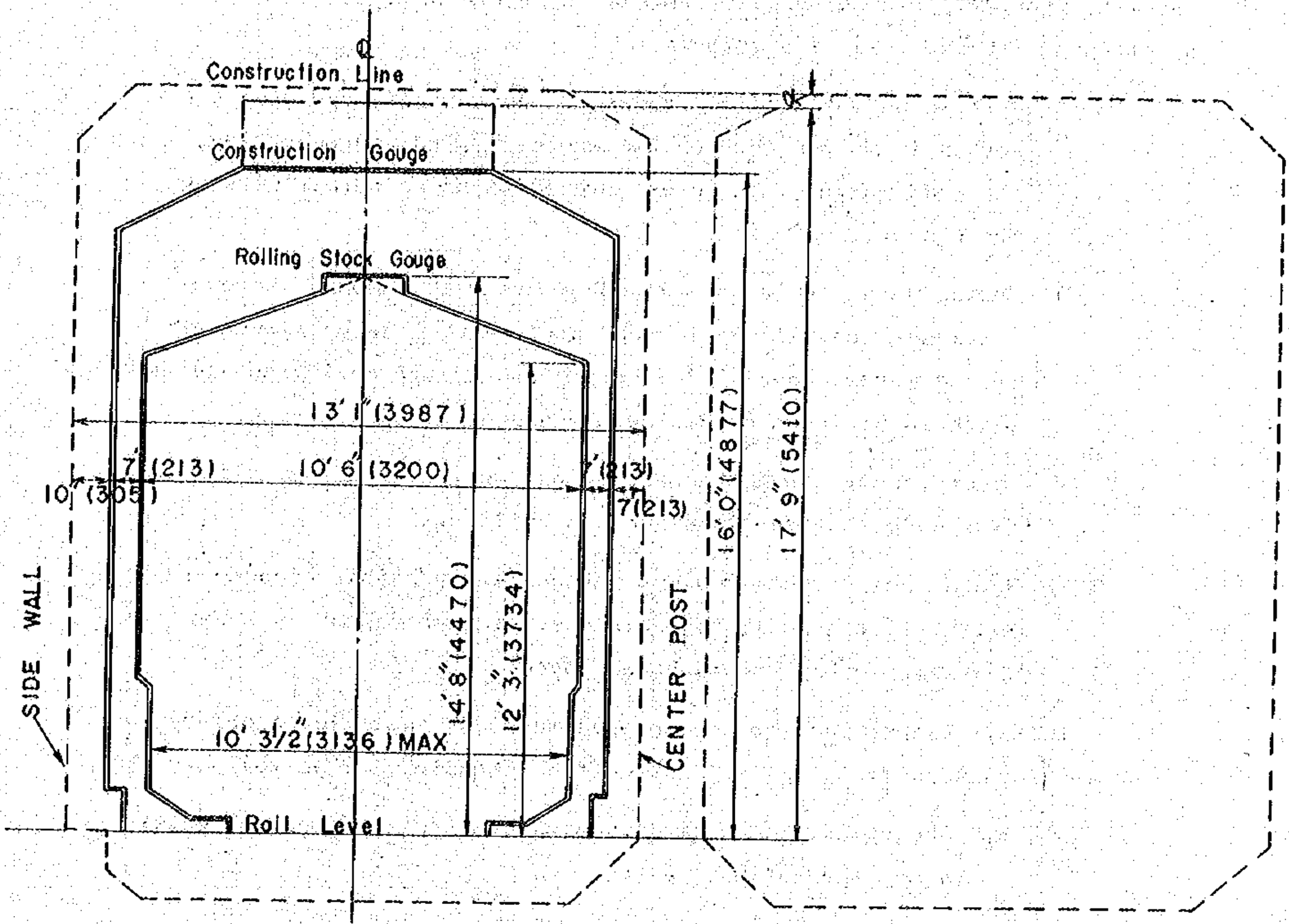
2) Baldia Branch

Where the Baldia Branch will be extended is composed of flat land topographically, as yet undeveloped. This line should run on the ground with major roads grade separated.

3) Korangi Branch

The Korangi Branch extension will run on a flat industrial zone close to the coast, with roads already completed. Therefore, the line should be grade separated from these roads, but running above the latter.

Fig. 12-5 Underground Railway Construction Gauge and Rolling Stock Gauge



12-6-2 Methods of Construction

The method of constructing the underground sections will be a specific problem. These sections should therefore be dealt with in accordance with the following methods.

1) Where a subway will run close to the surface, the open cut method is recommended on the whole. After open cutting, the road surface should be covered so as to permit working thereunder.

2) Spring water could be drained by means of pumps. However, if excavation will be impeded because of a large amount of spring water, special dewatering and waterproofing should be effected by means of wellpoints and chemical grouting.

3) Underpinning should be carried out where the subway will pass under obstructions such as buildings.

4) If the use of the open cut method is impossible because of extremely bad soil, the shield driving method or an other suitable method should be employed.

In addition to the above-mentioned methods, the major problems to be examined upon drafting of construction schedules are as follows.

a) Geological survey and pumping tests of underground water along the railway route.

b) Survey and detection of underground structures.

c) Traffic control measures to be taken during progress of work. (Fig. 12-6)

12-6-3 Linking the Rapid Transit System with the Existing Lines

(1) Spine

As part of the mass rapid transit system to be effected by way of railways, this study team suggested earlier in this report the electrification of the KCR line into a double-track line on a loop system and the electrification of the section between Karachi City Station and Pipri Station on the main line so as to largely improve its traffic capacity and thereby provide passengers with quality service.

Fig. 12-6(1) Shield Method

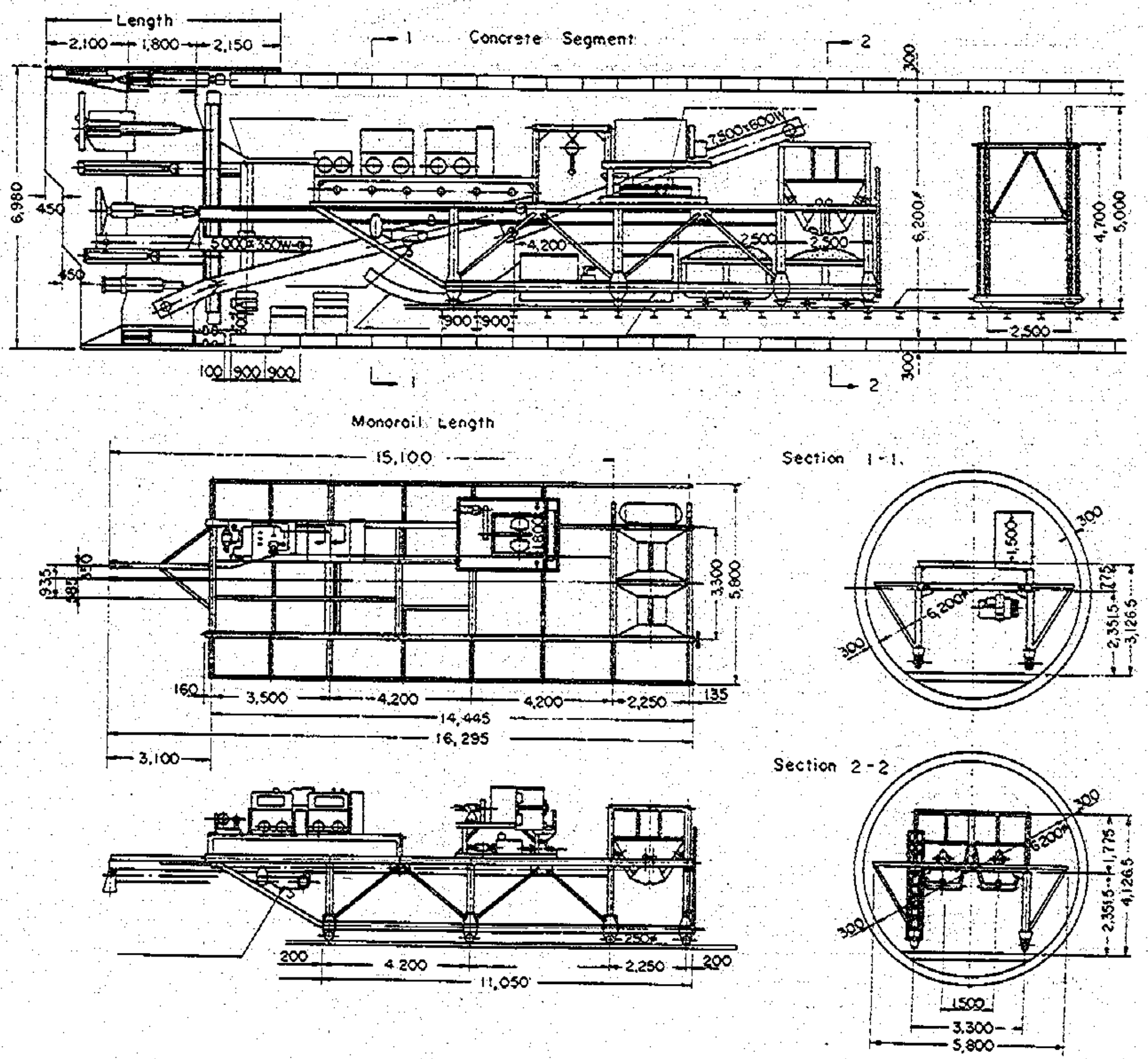
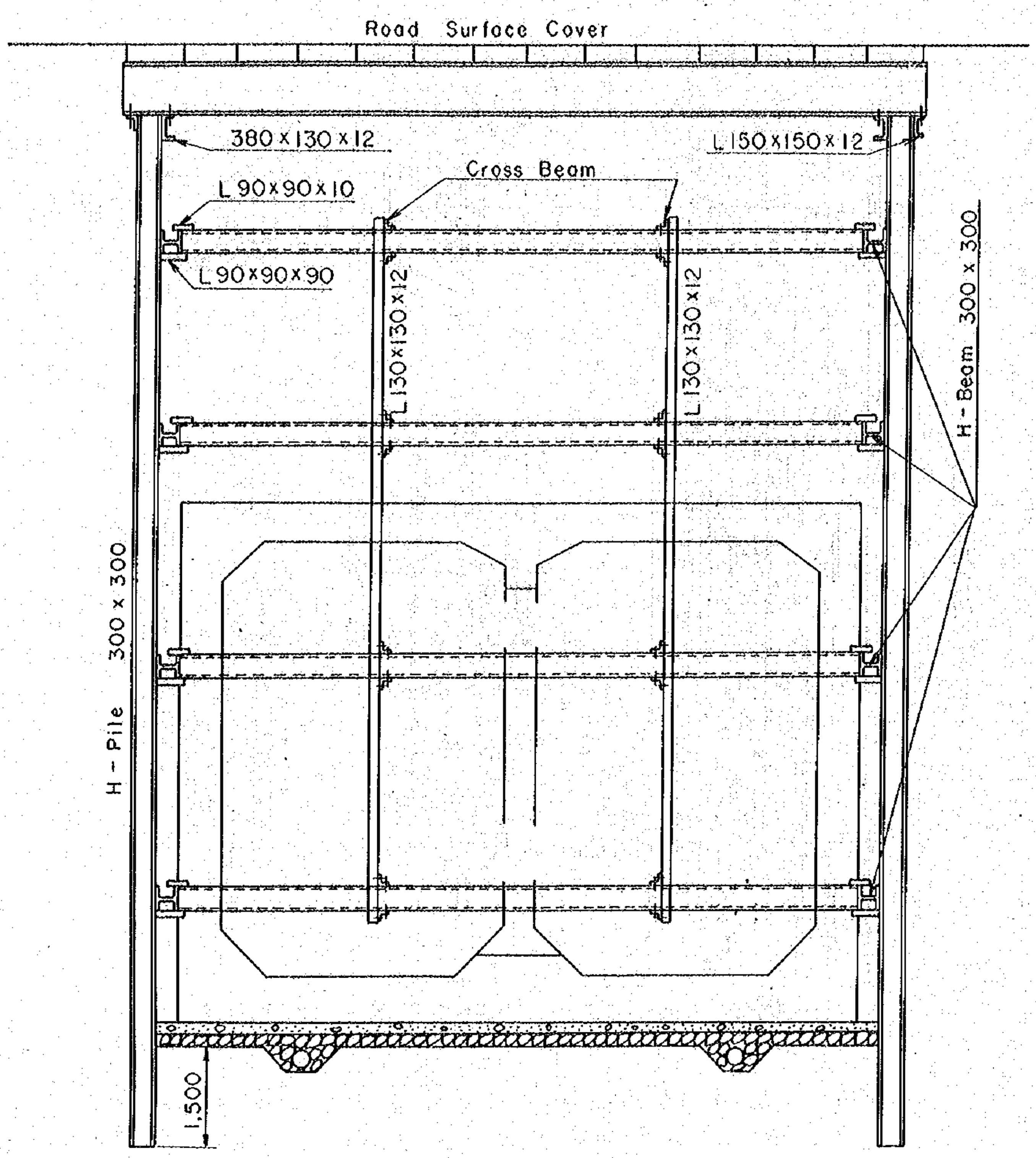


Fig. 12-6(2) Cut and Cover Method



For these purposes, the trackage right operation of the spine into the KCR line is one idea, but, if employed, will ironically form a bottleneck in transportation and may result in the decrease in the overall traffic capacity. Hence it would be better if the passengers be allowed to change from the KCR line to the spine at the separate operation.

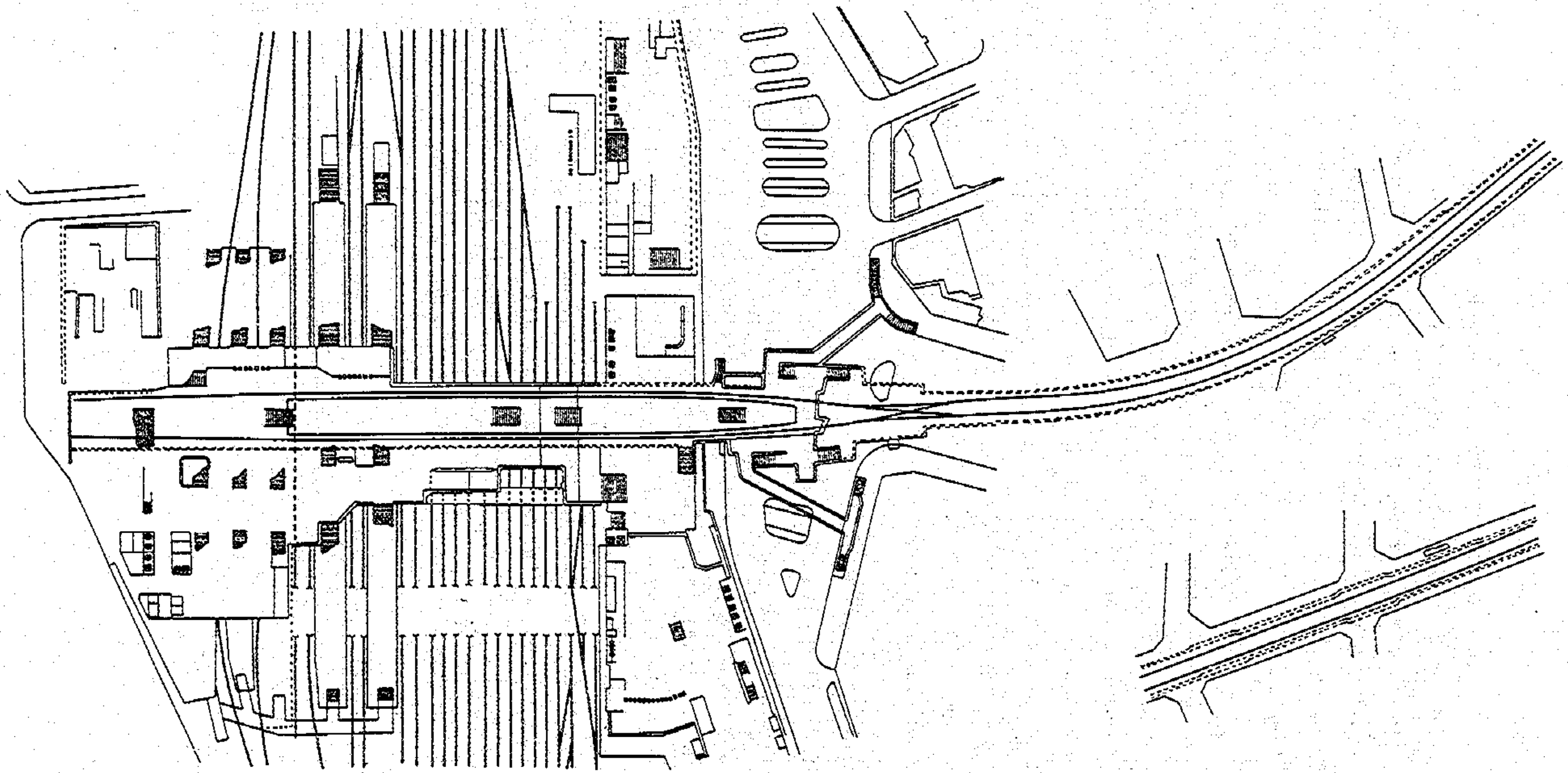
Admittedly, although the method of trackage right operation should be studied in detail from the view point of service to passengers, there is a new scheme to construct a new line apart from the extensions under consideration. Therefore, it is considered to be reasonable that the relationship with the construction of the planned new line and the situation of passenger flow should be re-examined before determining the method of trackage right operation. For information only, the diagram showing the relation between surface line and subway station is presented below. (Fig. 12-7)

(2) Extensions

As already described in Item (1) above, although trackage right operation of the extension lines into the KCR line would be considered unnecessary for the time being, sufficient study should be made for junction facilities connecting the extensions and the KCR line. Generally, the linking of the extensions to the KCR line should be put into practice after electrification of the KCR line into a double-track line has been completed. The construction of new junction platforms should be envisaged in accordance with the running directions of train.

However, should Project 1 overlap with Project 2 with respect to the period of time, it may be possible for the extensions to run into the KCR line if the latter has a margin in its track capacity. Therefore, a further study would have to be made in detail. (Fig. 12-8)

Fig. 12-7 Relation Between Surface Line and Subway Station



12-7. Linking the Existing Lines with other Mode of Traffic (Surface Traffic)

Generally, the objective of any traffic service is to carry passengers to their destinations. However, the complete fulfillment of such an objective is almost impossible even after the mass rapid railway transit system earlier proposed by this study team has been completed, for the use of other modes of transport such as buses and taxicabs is necessary together with this system to lead to the fulfillment of the objective.

Now, how the railways should be linked to other modes of traffic is a problem to be solved. It may well be said that the reasonable method of connecting these different modes of traffic should be effected with emphasis on the railways which overwhelmingly predominate all other modes of traffic. This would play a great role in alleviating the congestion of surface traffic and would inevitably increase the demand for railway traffic as well.

From this viewpoint, it is recommended that the junction facilities mentioned below should be provided with railway stations forming the hubs.

(1) Provision of Station Fronts

The front yards of most of the existing KCR line stations are confined and buildings and other structures intrude into them preventing the entry of buses and taxicabs. For this reason, these station fronts should be greatly enlarged and improved so as to permit free entry of buses and taxicabs. The following figure shows the two examples from Japan. (Figures 12-9 and 12-10)

(2) Provision of Parking Areas

In order that passengers coming off the railways be allowed to utilize buses and taxicabs waiting at station fronts and vice versa, station fronts should be provided with parking areas for the exclusive use of buses and taxicabs. These parking areas should be put under the control of the station, and private automobiles could be charged for admission. By doing so, the effect of increasing the utilization of the railways can be expected.

(3) Development and Improvement of Road Network Centering on Railway Stations

The existing major roads have almost no access to the stations, which decreases the degree of railway utilization while causing more congestion of surface traffic. For this reason, the measures to connect the major roads with the stations should be first taken to carry out the provisions (1) and (2) above, and thereafter the road network must be improved continuously with the stations being the center of such improvements.

(4) Rearrangement of Bus Routes

After a re-examination of the existing bus routes has been completed, they should be rearranged to establish the new routes which start from stations and run through and connect the neighboring housing areas, industrial zones and business regions or station with station. As a result of this rearrangement, the present bus operating distance may be reduced while increasing the operating frequency, thus markedly assisting the central area of the city in easing traffic congestion.

12-8. Obstructing Structures

As far as ground lines are concerned, there would be no definite and technical problems, except for those posed in limited areas. However, the following problems generally exist in the case of subway construction.

(1) Underground Utilities

Water distribution pipes, sewage pipes, telephone lines, electric conduct pipelines, gas distribution pipes and cables are often buried underground. Therefore, the subway should not be constructed at a depth of 2 to 3 meters from the ground surface, but at a greater depth. In this case, the accommodation of the above-mentioned pipes and cables in a utility culvert could also be considered.

(2) Buildings

In principle, the subway should not be permitted to pass under buildings. From the overall point of view, however, circumstances may force the subway to pass under buildings, and such buildings should be supported by underpinning.

Fig. 12-8 Example of Trackage Right Operation (Direction)

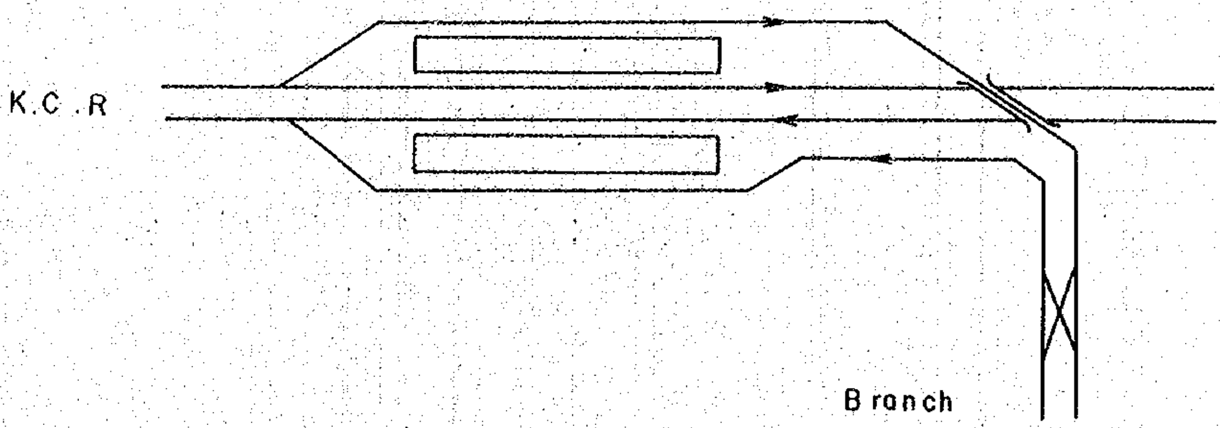


Fig. 12-9 Plan of KASHIWA Station Front (Ground Flow) S=1/500

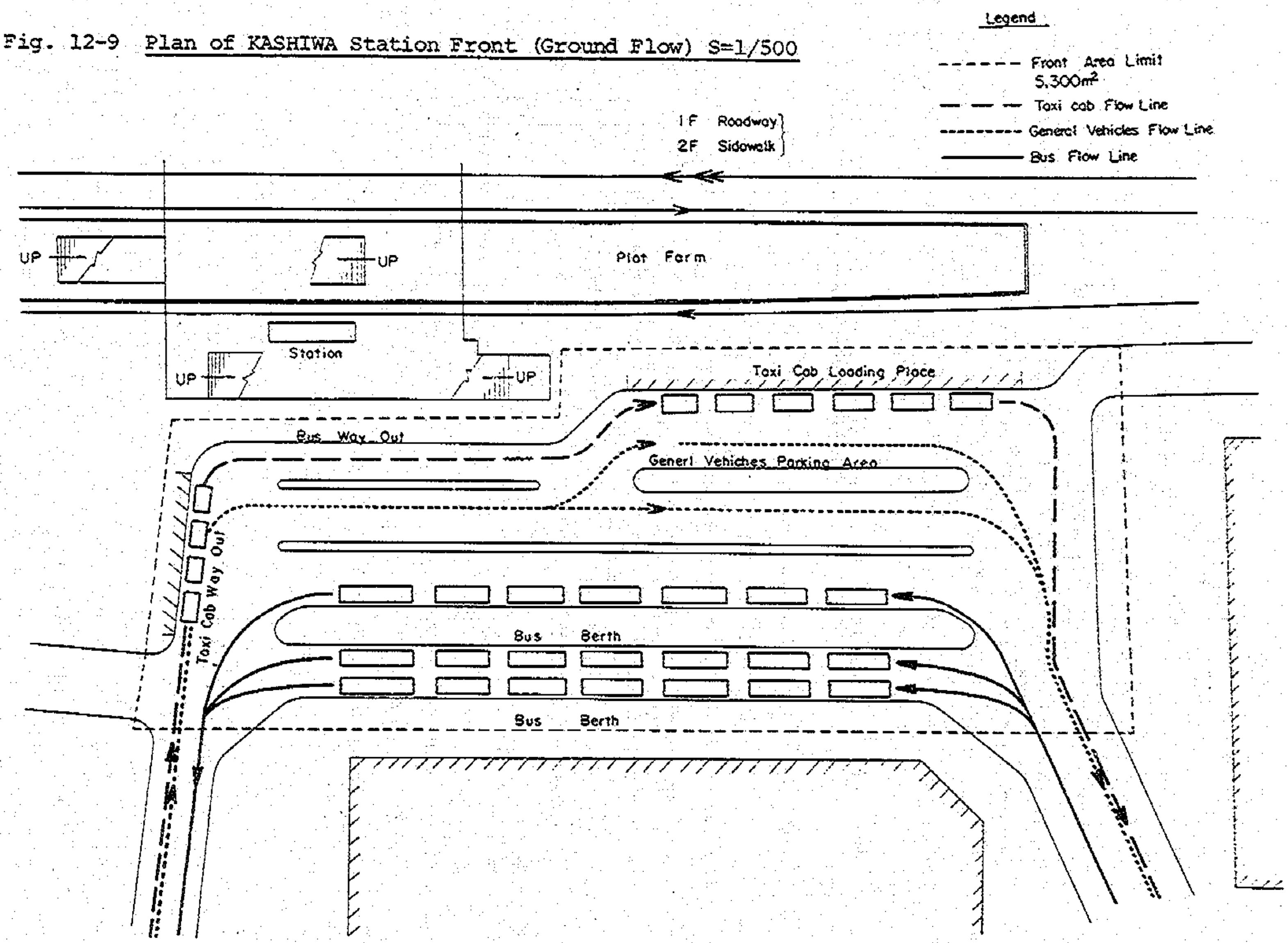
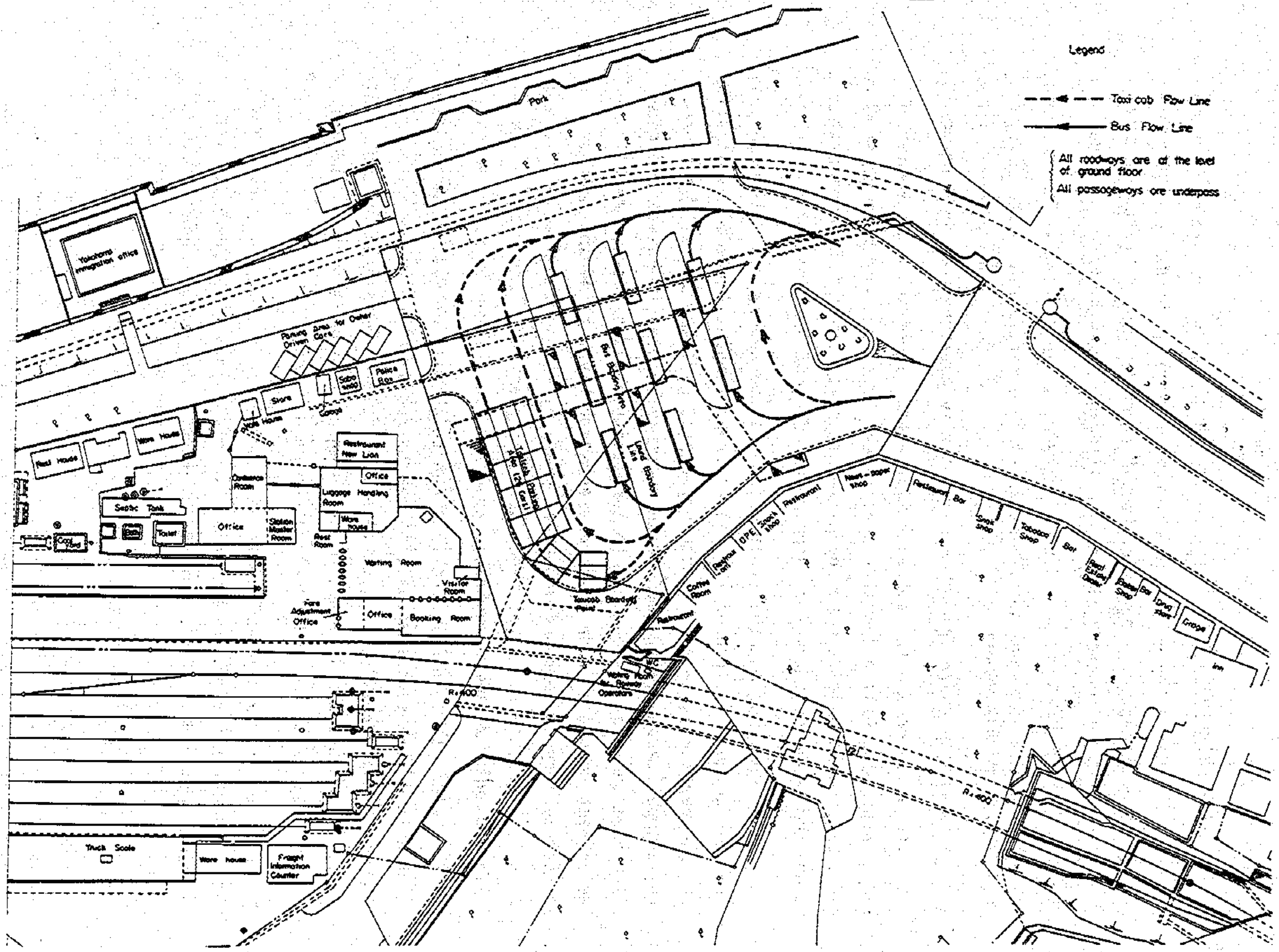


Fig. 12-10 YOKOSUKA Station Front (Ground Floor) S=1/500



(3) Rivers

Where the subway runs across a river, a bridge or tunnel should be constructed. However, if the river bed is to be tunneled to permit the subway to cross the river, allowance must be made for room under the river bed.

12-9. Construction Capability

Although there would be no problem in carrying out the construction of the spine and the extension lines with respect to the amount of work, a problem will arise if the construction of Project 1 overlaps that of Project 2 with respect to the period of time, which will naturally cause the concentration of a large amount of work.

In carrying out the construction of the subway, it will accompany problems which will involve the reduction of completion time, preparation of construction equipment and occurrence of spring water. Therefore, these problems should be studied in conjunction with technical cooperation from overseas. In order to construct urban railways, overall adjustment should be made with consideration given to administration, traffic policy and urban development plan.

12-10. Electrical and Signal Systems

Since it is considered that the spine will consist of an underground line with elevated parts as may be required and as described in the preceding paragraph. Therefore, electrical and signal systems, suitable for such conditions and of the simplest nature should be provided so as to facilitate their handling and maintenance.

For the extensions, there will not be many problems particularly as to electrification, because all the three lines are planned to run along relatively flat routes where there are many undeveloped areas.

12-10-1 Electricity System

The electrification of the spine under consideration will be by means of electric cars. The electricity system envisaged should be either of the alternate or direct current system. However, if the KCR line (including the main line) should use direct current after completion of electrification, the spine should also be electrified using the same system.

With respect to the sphere of car operation, the electric cars of both the spine and the KCR line should be allowed, at least at junction points, to run into other railway sections so as to permit common operation thereof. Installation of track-layout and overhead wire should be planned accordingly.

With regard to the extensions, if, as described above, the spine and the KCR line should be electrified by means of direct current, the extensions must also be electrified in the same way, for this would enable the KCR line, the spine and the extensions to interchange their vehicles and thereby enhance the operating efficiency of these vehicles.

12-10-2 Assurance of Power Supply

The receipt of electricity from KESC to the railway grid stations on the spine should be projected by means of the double backup system. This electricity will serve not only as a power source for train operation, but general distribution lines will also use this electricity in operating the drain pumps in underground sections, providing power for the lights and ventilators in underground tunnels. Therefore, assurance of these power sources should particularly be planned carefully. In addition, in order to provide back-up facilities in the case of trouble in the power transmission system, batteries or the AC generator equipped with an internal combustion engine, in either case as an emergency standby power source, should be available. Such equipment should preferably be provided at every underground station, and this is recommended with a view to reliability.

Also for the extensions, the electricity for train operation and the power source for signals must be of high reliability as in the case of the spine, but should be equipped with a backup system.

12-10-3 Signal System

In general, as a subway runs along many curves and slopes, the system of maintaining the safety of train operation must be determined considering the frequency and speeds of trains and relations with the existing railways. Safety systems used at present in Japan and foreign countries consist of:

(1) Cab warning system,
(2) Automatic train stop system,
(3) Automatic train control, and
(4) Automatic train operation.

Of the above systems, the automatic train stop system (2) has been used widely and is recognized to have a successful record.

For the spine, the employment of the electric automatic train stop system (equipped with a speed control device) is considered to be of high reliability even in a high-temperature and high-humidity area. However, should a future study of the spine find sharp curves and steep slopes following each other on the proposed route, the automatic train control system may also be considered. In either case, an automatic block system should be planned.

Meanwhile, as the extensions are predicted to consist of relatively flat track, it is considered that the automatic train stop system equipped with speed control device may be used based on color light signals using the automatic block system, similar to the signal system on the KCR line after modernization.

In addition to the above, the provision of CTC system and train radio system should be studied with respect to safety countermeasures in an emergency.

12-10-4 Induction and Telecommunications

Electromagnetic induction is largely affected by earth conductivity. The better the earth conductivity, the smaller the induction. According to the study so far carried out, earth conductivity is good generally in the coast line and poor in mountaneous areas and sandy areas.

In Karachi, although the study of neighboring telecommunication circuits failed to clarify how good their earth conductivity is because of insufficient data, these telecommunication circuits should be isolated or replaced by cable lines if induction is large.

12-11. Traffic, Rolling Stock and Required Facilities

12-11-1 Mission of Railway Division

Of the four lines; the R/T Spine, the Baldia Branch, the North

Karachi Branch and Korangi Branch, the R/T spine should run through the central area of Karachi, so as to constitute one of the major railway divisions dealing with the metropolitan traffic of Karachi together with the existing main line and the KCR line. Also, these three branches are spread radially from the KCR line being their main axis, thus will play an auxiliary role as an urban traffic system.

Therefore, the traffic layout should be established with the role of each section taken into account. It is mandatory that the R/T spine runs into Karachi City Station which is located at the center of Karachi, and R/T spine should be connected, on route, to the North Karachi Branch so as to effect through-operation reciprocally; this is considered to be highly beneficial.

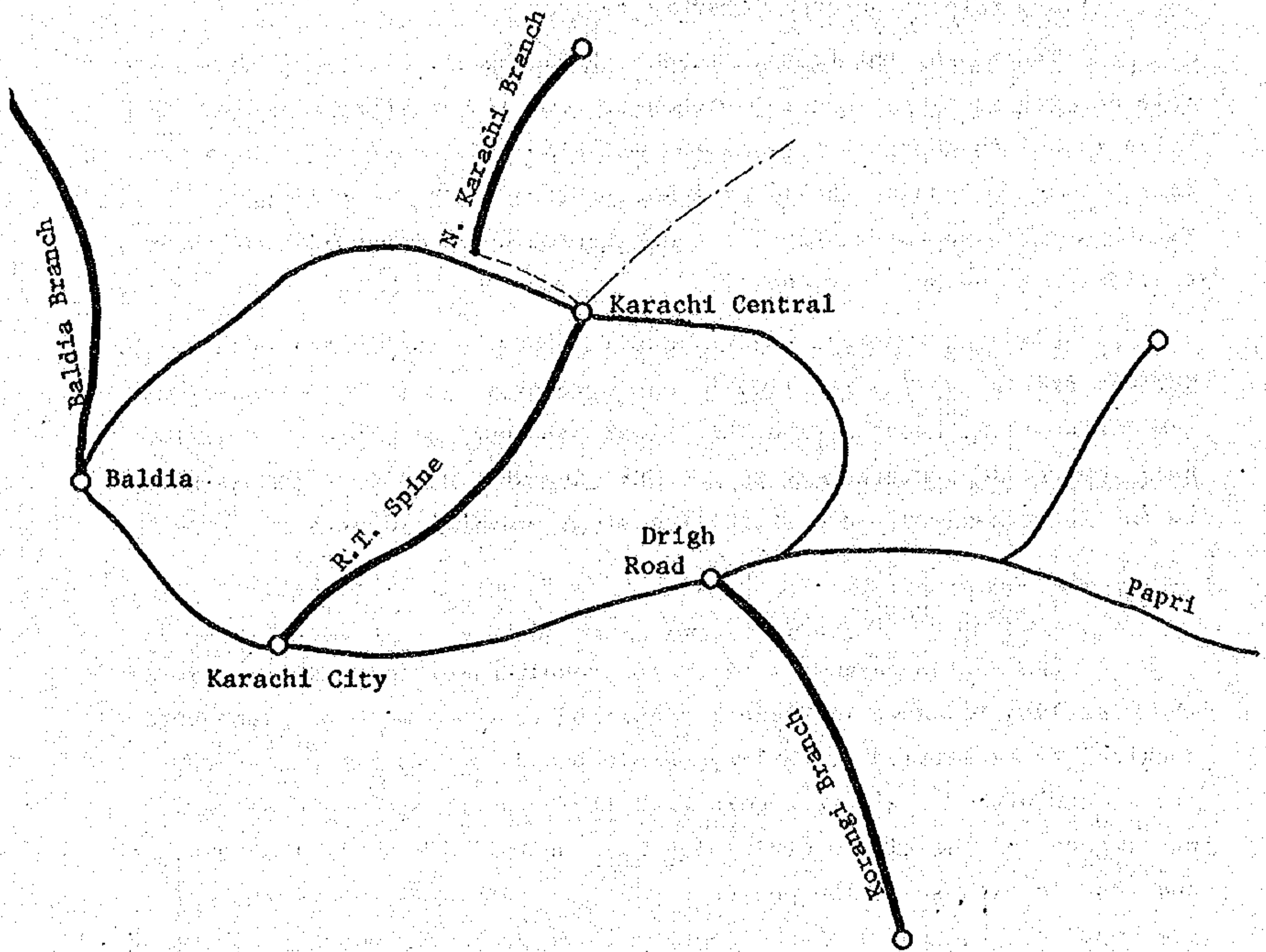
Although trackage right operation between the Baldia Branch, the Korangi Branch and the KCR line is not necessary, it is recommended that the former three branches and the R/T spine should be planned so as to have connected permanent way to the KCR line when consideration is given to the interchangeable use of rolling stock and their depots.

12-11-2 Train Operation

The estimated number of trains required for individual lines in the year 1985 is shown in Table 1 according to the number of passengers required to be carried by railways projected by the KDA; namely every train consists of 6 electric cars with the capacity per train being 900 passengers and the riding efficiency for the full day being 100 per cent and that in rush hours 150 per cent, and the percentage of trains per one hour the rush hours of the number of trains throughout the day being 20 per cent.

Since the each mileage of the R/T spine, the Baldia Branch and the Korangi Branch is approximately 6 miles (9.7 km) and that of the North Karachi Branch is approximately 3.4 miles (5.5 km), the schedule speed will be about 40 km per hour assuming that the average distance between stations of the respective divisions is 2 to 3 km. Table 2 shows the estimated train running time in minutes (including stopping time at stations) for each division calculated on the basis of the aforementioned parameters.

Fig. 12-11 Routes of Proposed Lines



Legend ——— Existing line

━━━ Proposed line

— - — - Future line

- - - - - Section where junction is considered necessary.

Table 12-1 Estimated Number of Trains

Category of Divisions	Rail mileage (km)	Number of electric cars per train	Capacity per train (passenger)	Number of trains throughout the day (one way)	
				through-out the day	per rush one hour
R/T spine	9.7	6	900	50	5 - 6
Baldia Branch	9.7	6	900	40	4 - 5
North Karachi Branch	5.5	6	900	35	3 - 4
Korangi Branch	9.7	6	900	25	3

Table 12-2 Estimated Running Speed and Time

Category of Divisions	Maximum speed (km/h)	Schedule speed (km/h)	Running time (minutes) (including stopping time)
R/T spine	90	40	15
Baldia Branch	90	40	15
North Karachi Branch	90	40	8
Korangi Branch	90	40	15

The required traffic volume in the year 2000 is, when compared with that in the year 1985, expected to grow by about 3 times on the R/T spine and 2 to 2.5 times on other three branches. Therefore, it is considered to be necessary in view of the magnitude of transport that both the R/T spine and the Baldia Branch be constructed as double-track lines from the very beginning, but the remaining two Branches may be single-track lines for the time being.

12-11-3 Rolling Stock

In order to save maintenance costs, staff and facilities, four new lines must use the same electric cars as the existing main line and the KCR line. Calculating the required number of electric cars for the year 1985 based on the required number of electric trains listed above, it will be about 120 electric cars (6 electric cars x 20 trains).

In consideration of the increase of traffic volume in the year 2000, the number of electric cars may have to be increased by about three times over the number in 1985.

12-11-4 Electric-Car Depot and Workshop

Assuming that four new lines use electric cars of the same construction as both the main line and the KCR line, maintenance thereof can be effected more advantageously; electric-car depot can handle the daily, regular and truck inspections and the workshop can perform important and overall inspections.

Although the scale of the electric-car depot, etc. depends on the time when it is required to be built, assuming that the time to start the operation of the R/T spine and the three other branches falls on or after 1985, the electric-car depot and workshop will be as follows.

(1) Electric-car depot

In the year 1985, the existing depot in Landhi will still have a margin in its inspection capacity, but will reach almost its maximum limit in storage capacity. Therefore, a new depot should be provided for common use of the R/T spine and the three branches, preferably at Karachi Central which will become the center of the four divisions. In early stages, the provision of only electric-car storage tracks, daily inspection tracks and washing tracks will be sufficient as the depot facilities. (For regular inspections, the regular inspection facility of the electric-car depot in Landhi may be used.) Therefore, sufficient land, etc. to accomodate the regular and truck inspection facilities required to be provided in the future should be acquired in advance so as to avoid working backward.

(2) Electric car workshop

In order to cope with handling the electric cars of the main and KCR lines, the addition of proper facilities to the Karachi Kantt workshop is considered sufficient. Also, such lines as are considered to have additional divisions newly provided in the year 2000, other than the R/T spine and the three lines, are predicted to use about 1,000 electric cars including those of the existing lines, hence a workshop for exclusive use by electric cars will be required in the future. The time for construction of this workshop should be determined in conjunction with the increase of electric cars on both the main and KCR lines.