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8389 Hong Kong Mass Transit Railway Modified Initial System: system planning and multi-contract procedures

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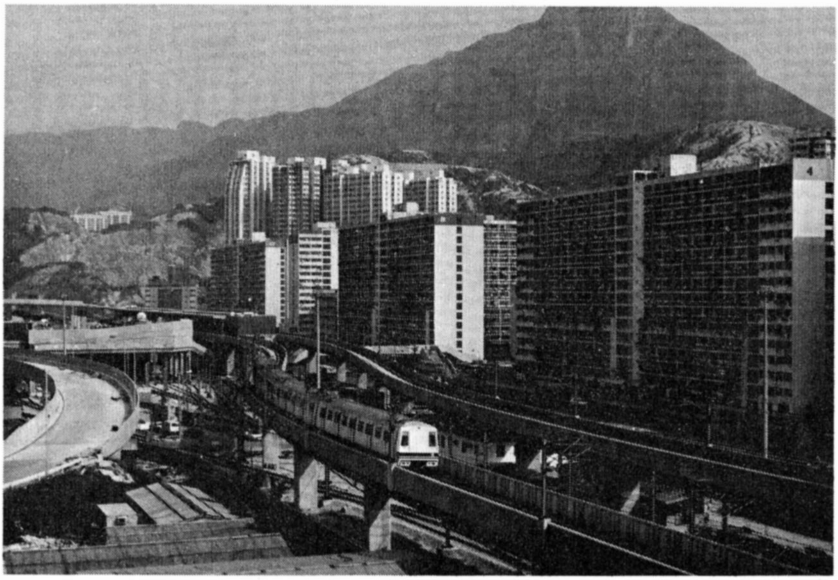

This Paper describes the detailed planning of the Modified Initial System of the Hong Kong Mass Transit Railway including development of the plan for its implementation and the selection of the form of contract. It also deals briefly with the cost-estimating and the verification of the estimates which led to the final decision to proceed with construction. The Paper sets the background for the three companion papers which describe the detailed structural design and construction of the railway.

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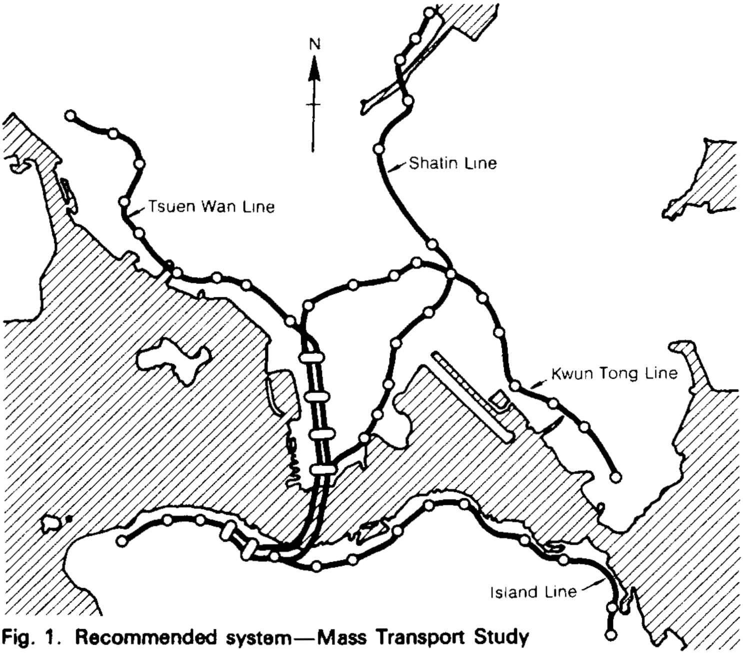


Fig. 1. Recommended system—Mass Transport Study

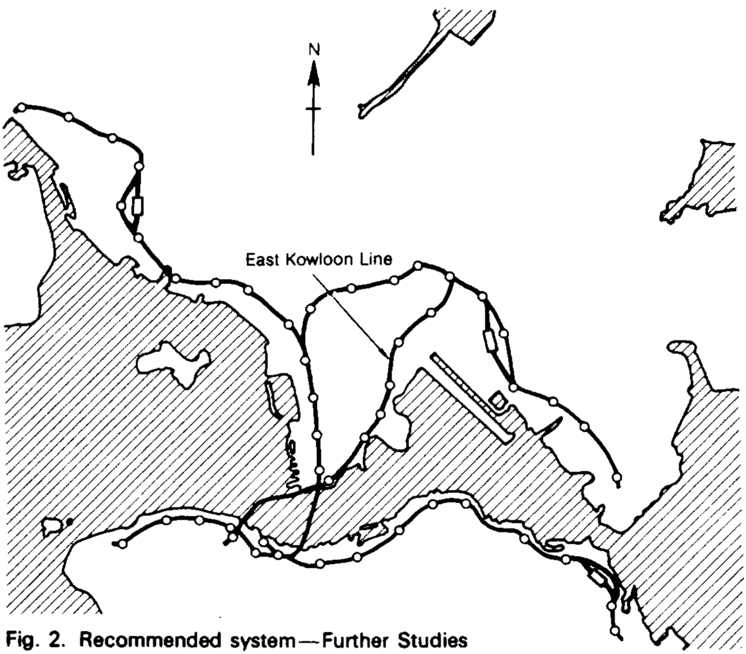


Fig. 2. Recommended system—Further Studies

Introduction

The basic planning of the Hong Kong Mass Transit Railway (MTR) has been described in detail in an earlier paper[1] and only a brief summary is given here.

2. In 1965, the Hong Kong Government commissioned Freeman Fox, Wilbur Smith and Associates to undertake a study into the mass transport needs of Hong Kong. Various public transport alternatives were considered in this study but, in

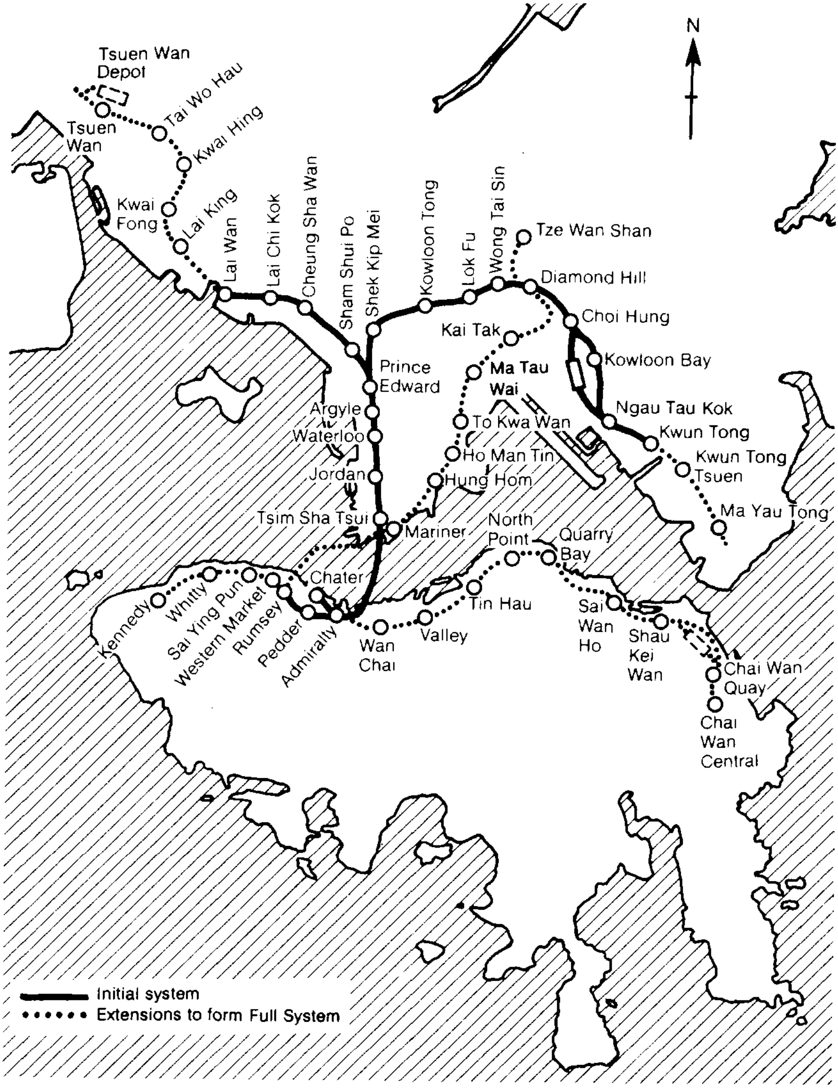


Fig. 3. Full System

their report submitted in September 1967, the consultants recommended the construction of a mass transit system as outlined in Fig. 1.

3. In 1969, the Government appointed Freeman Fox & Partners to carry out further studies to confirm the extent and detailed alignment of the MTR system. The study looked in greater depth into the design of the system from both the engineering and operational viewpoints to identify a staged programme of construction and an initial system which served those areas where the surface traffic was most congested, and also to enable reasonable estimates to be made of the cost of the system and its financial viability. The system recommended in the Further Studies Report in August 1970 is outlined in Fig. 2. Fig. 3 shows the system after modification (at Mongkok and Diamond Hill) to improve the operational aspects and form the Full System adopted by the Mass Transit Railway Corporation in 1977.

4. Following the Government decision to construct a mass transit railway, Freeman Fox & Partners (Far East) commenced detailed design of the Initial System in July 1972. Subsequently, following the withdrawal of a turnkey bid by a Japanese consortium, the size of the system to be constructed initially was reduced and the Modified Initial System (MIS) was developed as shown in Fig. 4. The MIS comprises 15·6 route kilometres and forms the heart of the Full System shown in Fig. 3; 12·8 km of line and twelve stations are underground while 2·8 km and three stations are elevated.

5. The Modified Initial System has been constructed and is being operated by the Hong Kong Mass Transit Railway Corporation which was established in 1975, replacing earlier temporary bodies. They continued the existing appointment of the consulting engineers. Freeman Fox & Partners (Far East), the Principal Consultants, engaged the associated firms shown in Fig. 5. The construction commenced in November 1975 and the first section of line was opened to public service on 1 October, 1979, the second in December and the final section was opened by Her Royal Highness Princess Alexandra on 12 February, 1980, some 9 weeks ahead of programme.

System planning

6. It is important for any metro system to attract the maximum number of passengers and this is particularly true in Hong Kong where the system was required by Government to meet the whole capital and operating costs out of fare revenue. To attract passengers it is essential that the system be convenient to use, and the major factors affecting convenience are the location of stations and the careful design of interchanges to permit easy transfer from one line to another. It is also important that the system be attractive and comfortable.

7. All these factors have to be set against the need to minimize cost. The complexity and interrelation of planning and engineering parameters require close co-ordination to achieve the optimum solution. Fig. 5 illustrates the lines of communication between the consultant firms. There was a close working relationship with Government and the MTRC at all levels.

Traffic forecasts

8. The traffic forecasts for the MTR all originate from the Mass Transport Study. These were based on origin and destination surveys and home interview surveys carried out in 1966. Design year forecasts for 1986 were based on Government forecasts of population, income growth and land use.

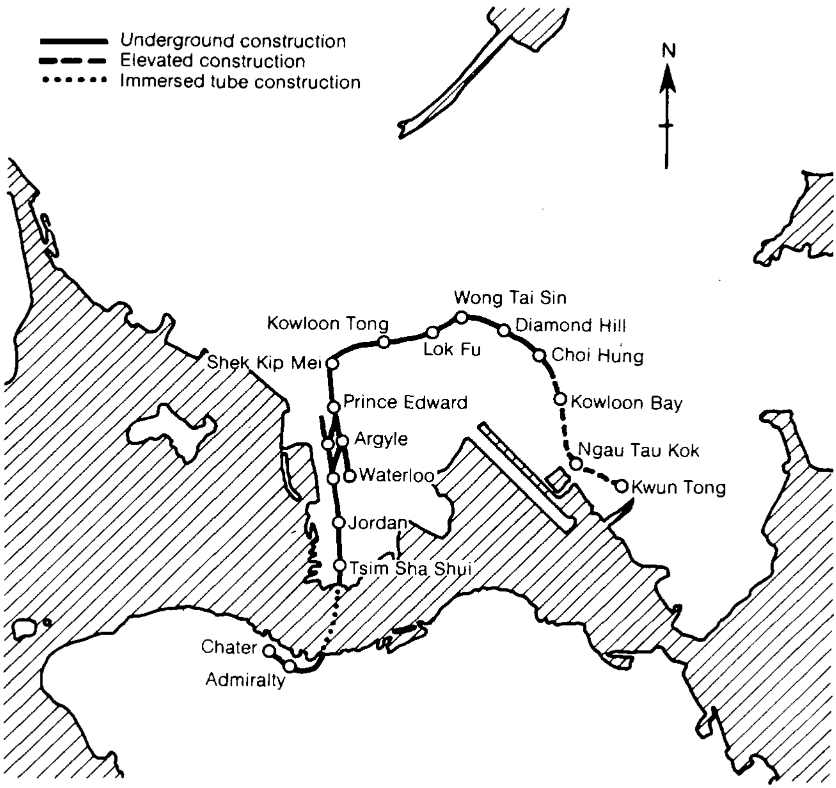
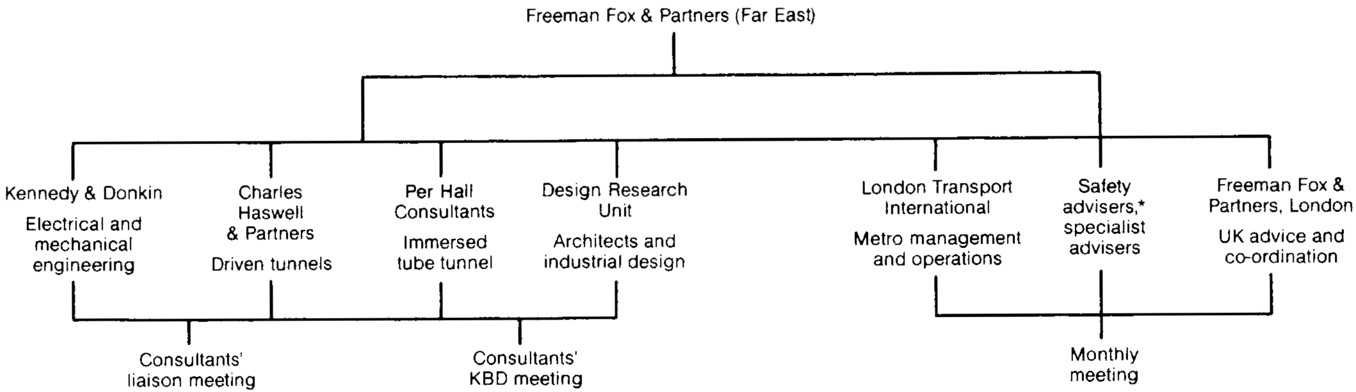


Fig. 4. *Modified Initial System*

9. In the Further Studies, the same basic data was used but adjustments were made to take account of revised population and land use forecasts. The forecast traffic for the recommended full system is shown in Fig. 6.

10. These figures, together with data regarding trip purposes, were used to estimate the passenger flows on each link of the complete system network for a 2 min period during the morning peak. The figures were derived by assuming that 13% of the 24 h traffic moved during the peak hour and that half of this was spread over 20 min of the peak hour; the direction of flow of traffic was estimated by assuming that a high proportion of morning peak traffic was from home to work, with only a small proportion from work to home and other purposes. A typical section of the peak 2 min network is shown in Fig. 7. During the course of construction, updated traffic forecasts arising from the Comprehensive Transport Study commissioned by Government were used to confirm the initial provision of escalators in the MIS, but these forecasts were too late to influence basic station designs.



*Safety advisers: the late Col. McMullen, the late Col. Robertson and UK Railway Inspectorate

Fig. 5. Consultants' organization

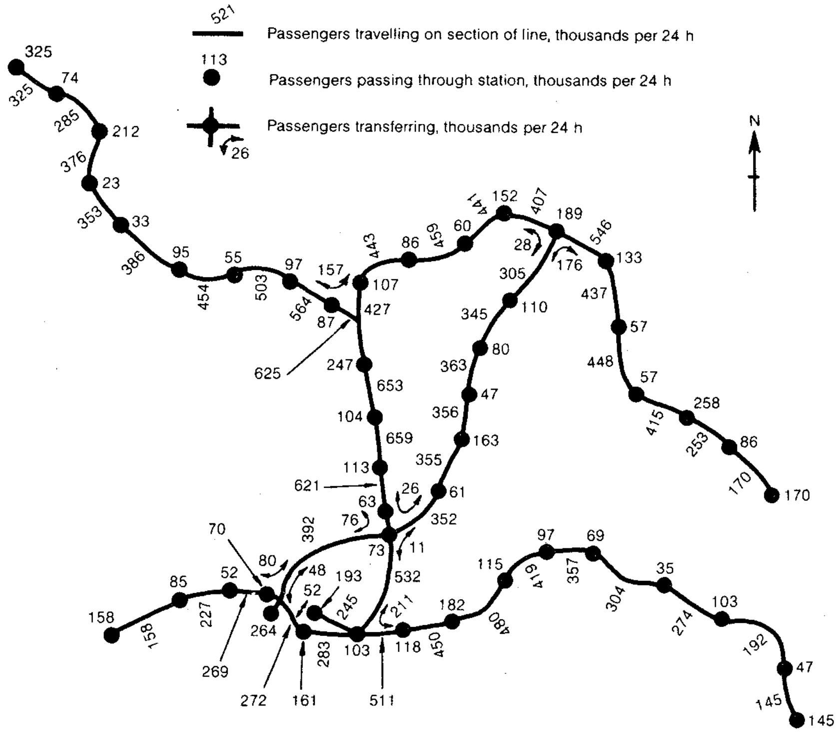


Fig. 6. Further Studies traffic forecasts

Interchange between lines

11. There are five locations (Fig. 3) where interchange is planned between different lines of the system:

Tsuen Wan Line and Kwun Tong Line	at Prince Edward, Argyle and Waterloo
Tsuen Wan Line and Island Line	at Admiralty and Chater/ Pedder
Tsuen Wan Line and East Kowloon Line	at Tsim Sha Tsui/Mariner
Kwun Tong Line and East Kowloon Line	at Diamond Hill
Island Line and East Kowloon Line	at Western Market/Rumsey

The first four of these were given very careful consideration in the design of the MIS to ensure efficient passenger interchange as the system was extended.

12. The transfer arrangements at Prince Edward, Argyle and Waterloo are illustrated in Fig. 8. This arrangement, which was selected after a detailed assessment of 21 alternative schemes, terminates Kwun Tong trains at the lower level at Waterloo and runs Tsuen Wan trains through to Jordan and stations south to Hong Kong Island. Cross-platform transfer is provided at Prince Edward for passengers between the northern arms of the Kwun Tong and Tsuen Wan lines, and

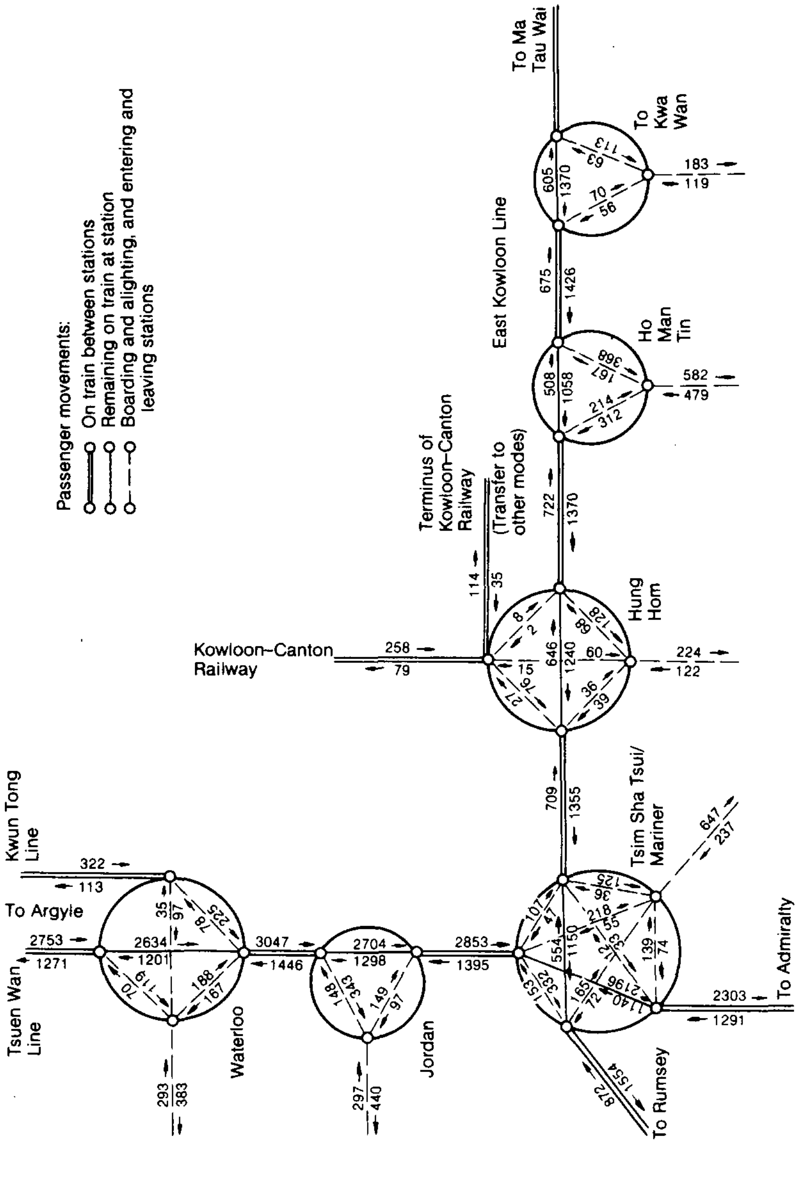


Fig. 7. Morning 2 min line loadings—part plan

at Argyle between the Kwun Tong Line and the southern part of the Tsuen Wan Line. Passengers can also transfer vertically between the two lines at Waterloo, which will constitute an overflow in the event that Argyle becomes too crowded. The track is aligned so that the Kwun Tong Line can be extended southwards in the future either along Nathan Road or towards Hung Hom.

13. Figure 9 shows how cross-platform transfer is provided at Admiralty between the Tsuen Wan Line and the eastern half of the future Island Line while transfer with the western half is catered for at Chater/Pedder. Sidings below Chater station are accessible from both the Tsuen Wan Line and the Island Line and are used for maintenance access between the two.

14. The interchange between Tsim Sha Tsui and Mariner stations is the one of least importance since forecasts of transfer traffic are relatively low. Constraints on the alignment result in the two stations being about 100 m apart. Provision has been made in the MIS construction for a passage connecting the paid areas of the two stations.

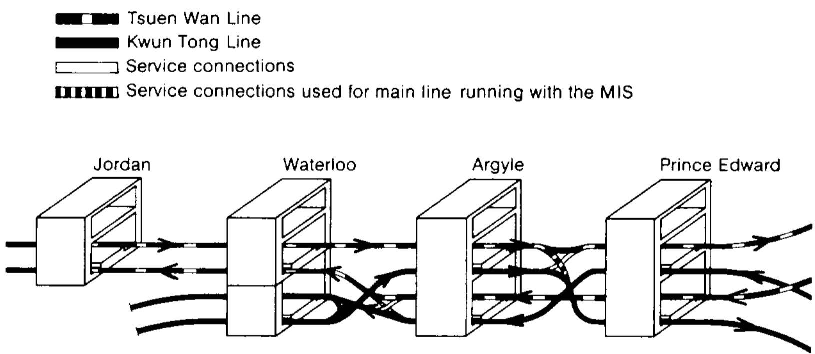


Fig. 8. Tsuen Wan/Kwun Tong line interchange

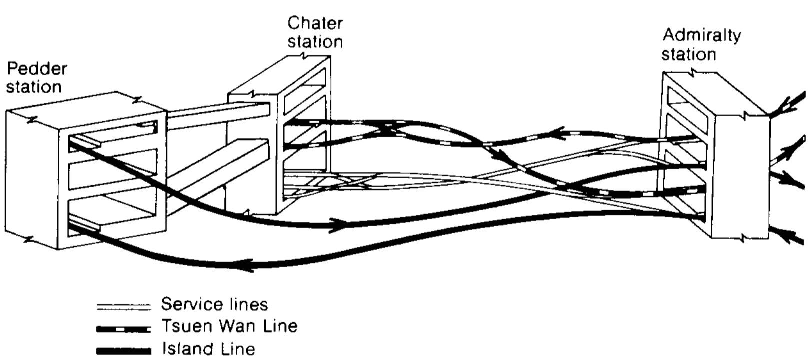


Fig. 9. Tsuen Wan/Island line interchange

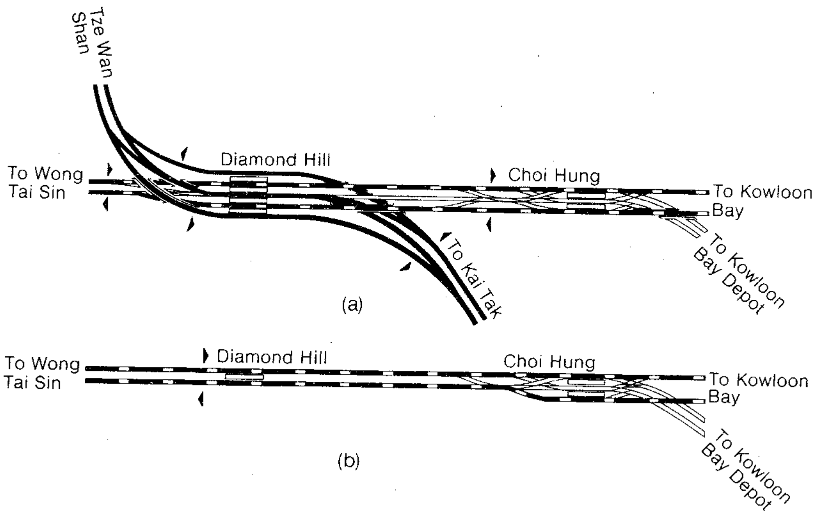


Fig. 10. Kwun Tong/East Kowloon line interchange at Diamond Hill: (a) Full System layout; (b) MIS layout

15. It was originally proposed that the East Kowloon Line would terminate at Diamond Hill but with high interchange forecasts a satisfactory layout could not be achieved. The arrangement shown in Fig. 10 provides cross-platform transfer for the major movements. While the total civil cost is greater, due to the extension of the East Kowloon Line by one station, the facility for staged construction of Diamond Hill station resulted in a much reduced cost in the MIS. Also additional traffic will be generated by the extra station at Tze Wan Shan which has a population of about 150 000.

16. The interchange between Rumsey and Western Market stations will be potentially large and, as at Tsim Sha Tsui, the stations will be physically separate. Little detailed planning of the interchange has been carried out since neither station forms part of the MIS.

Passenger handling in stations

17. The platforms in the stations are 182·5 m long to handle trains of 181·5 m with a tolerance of $\pm 0{\cdot}5$ m in the stopping position. Typically stations have an island platform between two tracks as shown in Fig. 11. The platform comprises a

Table 1. Theoretical passenger movement rates (persons/minute)

Staircases per 1 m width:*	
up	63
down	70
Escalators 1 m wide	135
Passages and ramps per 1 m width*	88·5

* Rates apply to passages exceeding 1·8 m width.

central zone, in which escalators and stairs giving access to a concourse above are located, with a minimum clear width of 3 m provided between this zone and the platform edge. At more heavily loaded stations a greater platform width was provided where possible using the formula $W = 0{\cdot}5N/182{\cdot}5 + 0{\cdot}45$, where W = platform width in metres, and N = 2 min peak forecast of boarding and alighting passengers.

18. Escalators have normally been provided for all vertical movements between concourse and platforms. Based on actual measurements of escalator flows on existing systems, escalator capacity was taken as 150 persons/min. However, it would be unwise to design a new system to such a figure and so, to take account of errors in traffic forecasts, irregularities in train headway, uneven loading between escalators and local peaks in travel demand, the escalators were down-rated for design purposes. For flows from platform to concourse they were down-rated to 60% (90 persons/min) and for the reverse movement to 70% (105 persons/min). The lower rating for passengers leaving from the platforms recognized that the risks associated with congestion were much greater at platform level than at concourse level.

19. These design capacities and the 2 min peak forecast were used to determine the number of escalators required at each station. One stair is provided in each case for use by passengers who do not wish to use an escalator and as back-up in the event of an escalator being out of service.

20. Figure 12 shows the layout for a typical station. The escalator arrangement caters for the projected Full System traffic and is designed to minimize conflict between incoming and outgoing passengers at both levels within the paid area. Outside the paid area some conflict is inevitable but the area is planned to avoid this conflict interfering with the flow in the ticket issuing area. In the MIS only four escalators have been installed out of the six allowed for in the station design.

21. The fare collection for the MTR is entirely automatic (AFC) using magnetically encoded single-ride tickets of credit card size which are issued by coin-operated machines. The equipment is programmed for multi-ride tickets which will be introduced as traffic increases.

22. The long narrow concourse shown in Fig. 12 is dictated by site constraints and cost considerations. The width of concourse is defined by the width at platform level and the total length by the space required for passenger handling, staff rooms, offices and plant rooms.

Station entrances

23. The narrow shape of the concourse places a constraint on the positioning of the entrances since they cannot be located within 20 m of a paid area to avoid conflict in the ticket issuing zones. This constraint has not normally been a major problem, however, and the positioning of entrances as shown in Fig. 12 gives a good spread of entrances at ground level, thus increasing the catchment zone of the station. For example, while the distance between Waterloo and Argyle stations is 760 m, the distance between entrances is only 500 m.

24. Figure 13 illustrates two typical entrance arrangements. The concourse of a station is generally about 10 m below ground level, the actual level being controlled by need for the station roof to be below the numerous utilities which fill the streets of Hong Kong. Stairs are used for the upper 5 m to minimize the space occupied at ground level, with an escalator for the upward movement at the lower level.

25. The capacity of entrances is calculated using the basic capacity criteria

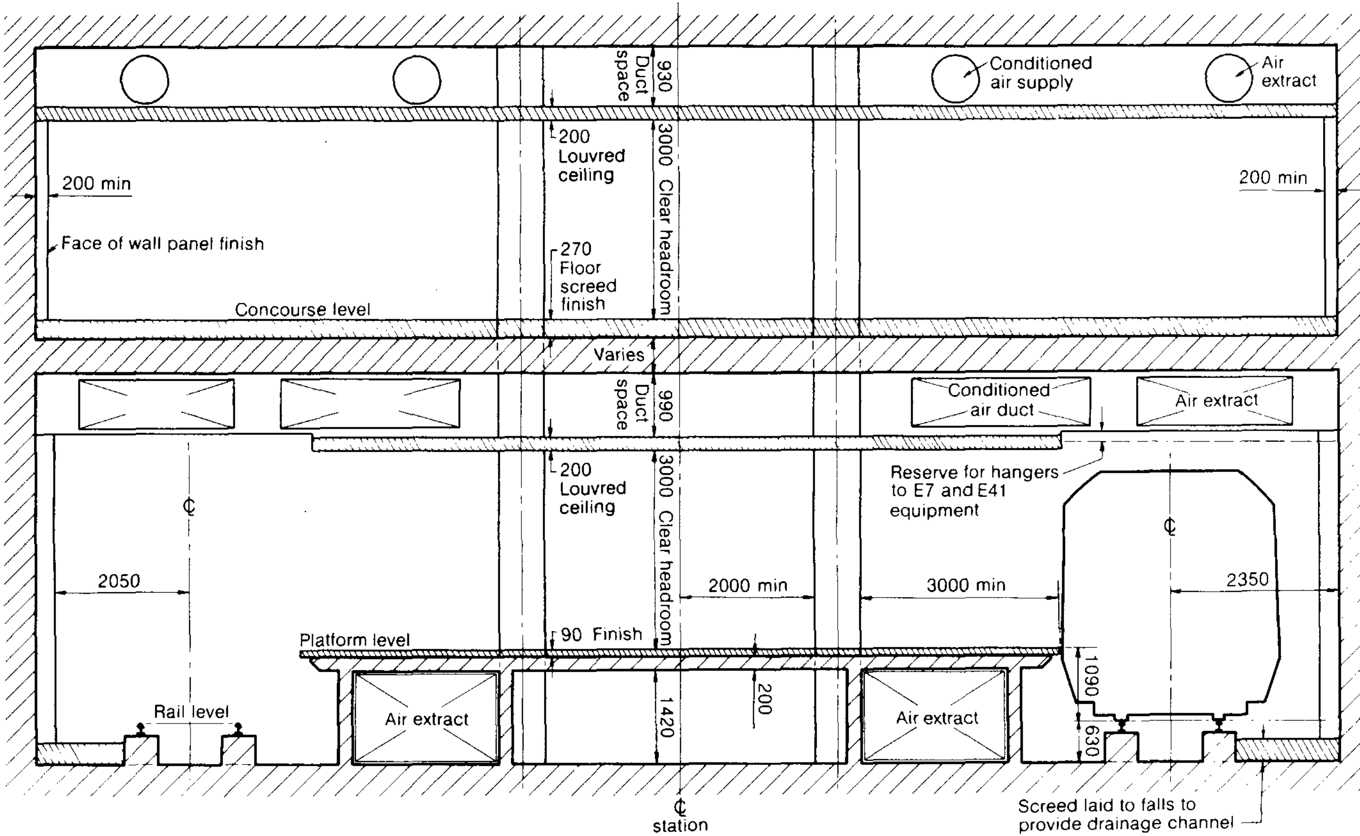


Fig. 11. Typical station cross-section (dimensions in millimetres)

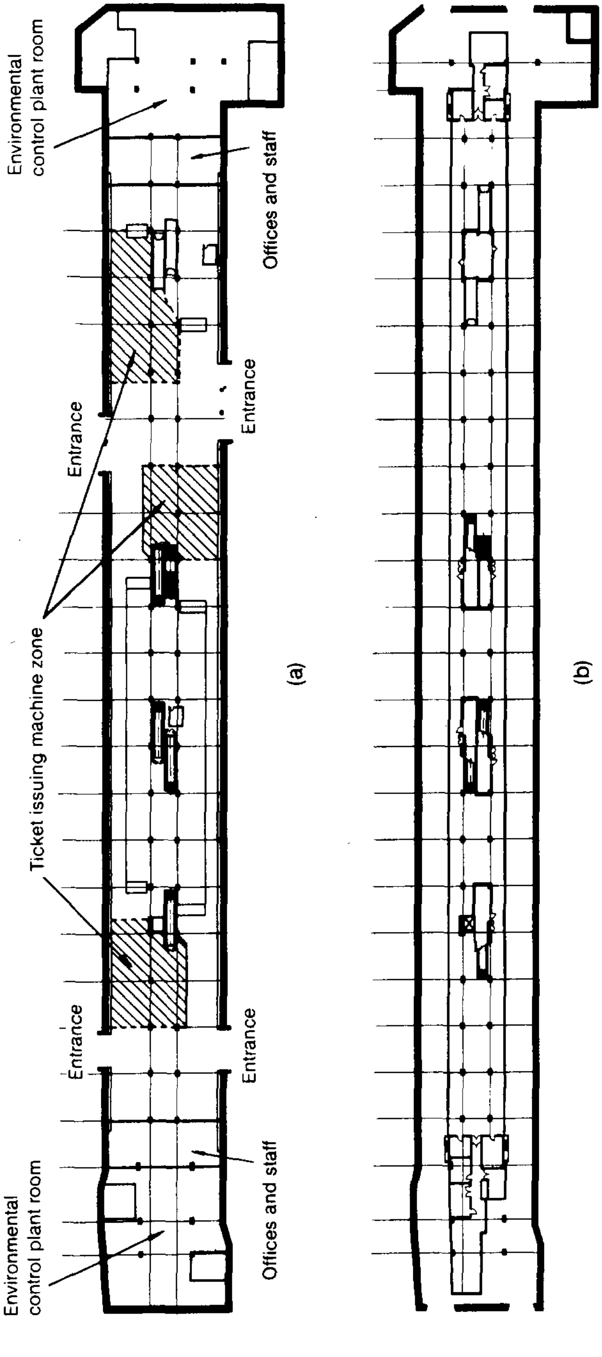


Fig. 12. Plans of typical station: (a) concourse level; (b) platform level

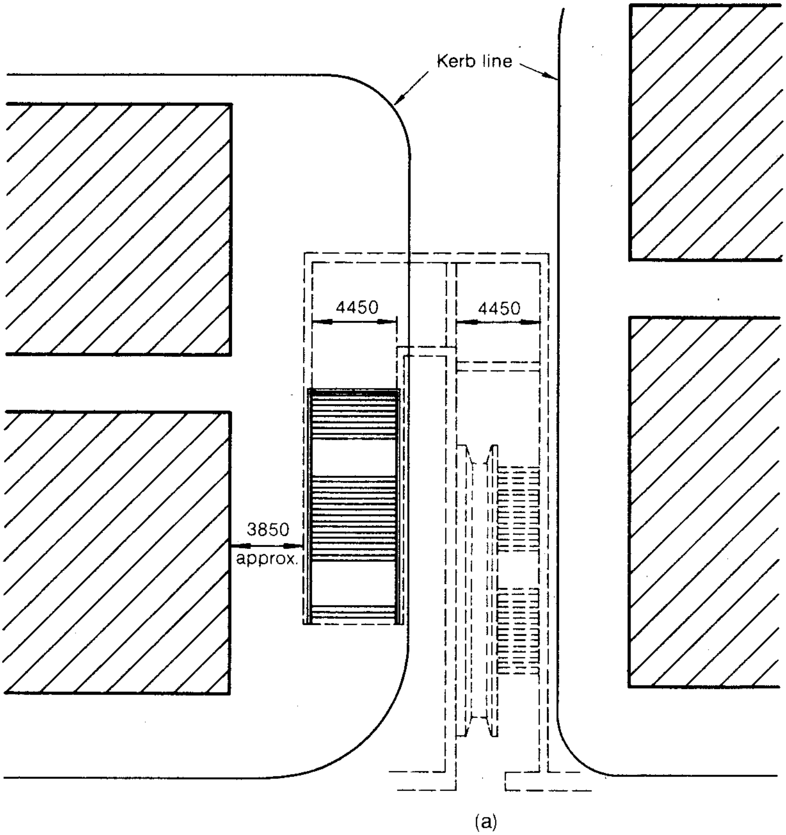
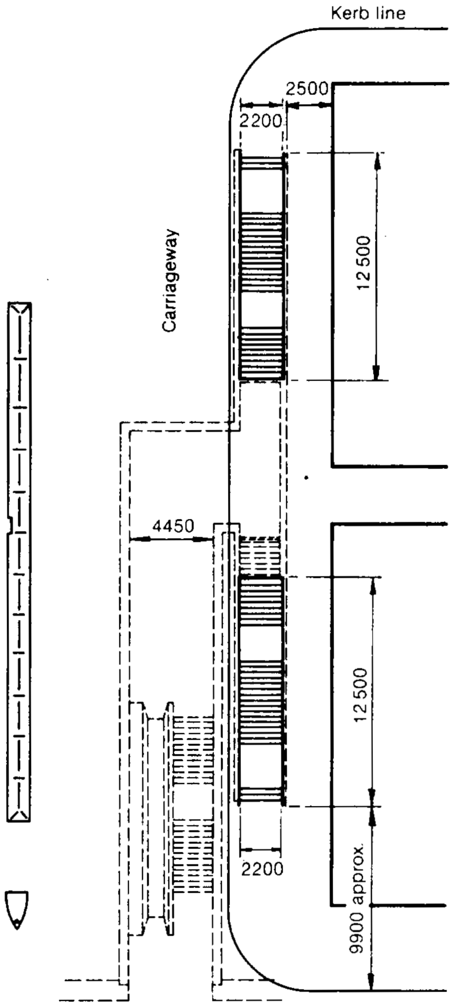


Fig. 13 (above and right). Typical entrance layouts (dimensions in millimetres)

given in Table 1. The entrance escalators are slower than the internal ones, hence the lower basic capacity. In calculating the number required, the entrances were down-rated to 50% to allow for imbalance of flow between individual entrances and also for escalators out of service. Double-size entrances have been used in some locations and in others provision has been made for directional imbalance of peak flows. Where entrances are deeper than 10 m, escalators have also been used where possible for the downward movement.

26. The entrances were located as near as possible to the major traffic generators in the area, given the ground level constraints and the limitations on entrance positions at the concourse. Other factors considered in the positioning of entrances were interchange with surface public transport and park-and-ride and kiss-and-ride facilities. With entrances located on both sides of major highways, it is inevitable that the stations will be used as pedestrian subways. Thus, where physically possible and where pedestrian cross-street flows justified it, the MTR entrances were combined with a pedestrian subway facility above the station roof. In this event and



(b)

where significant flows through the concourse could be expected, additional capacity was provided in the entrances. Fig. 14 shows how two pedestrian subways have been provided at Argyle station. Similar subways are provided at Diamond Hill, Wong Tai Sin, Waterloo and Tsim Sha Tsui stations.

Station offices and staff facilities

27. Figure 12 shows the space provided for offices and staff facilities. There is one booking office at each concourse which has an information counter and

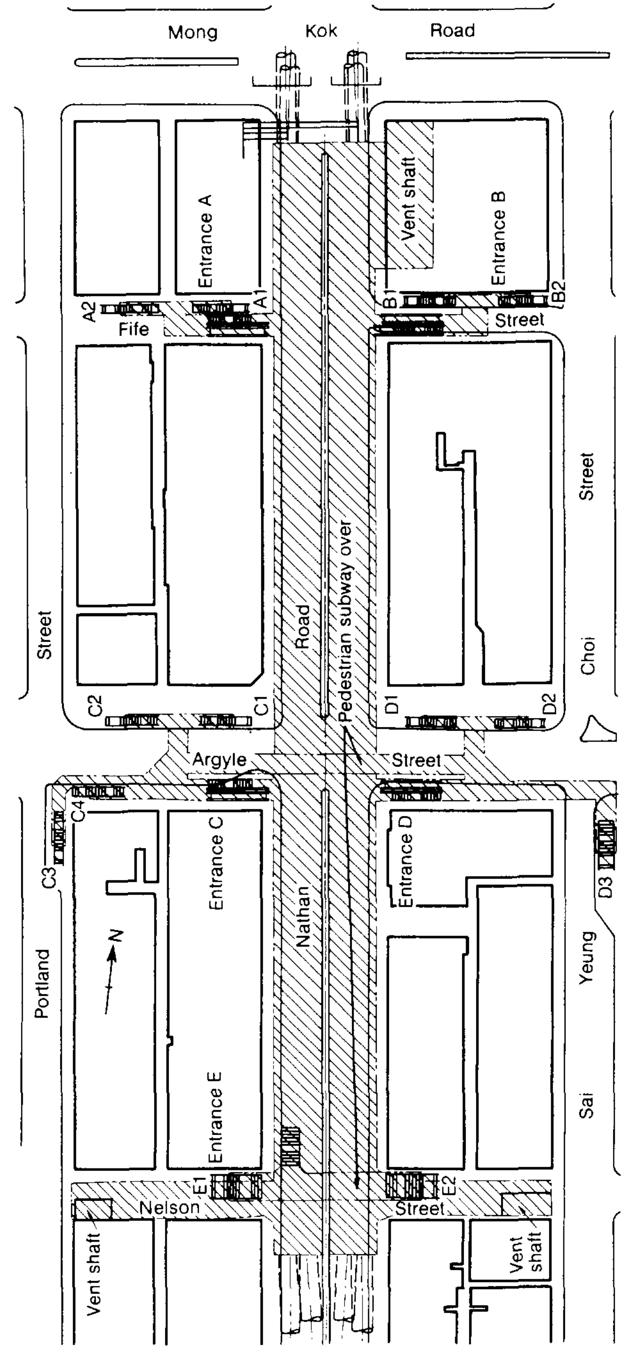


Fig. 14. Argyle station: ground level plan

counters for the future sale of multi-ride tickets. This office, and an associated audit office and AFC room, house equipment for the automatic monitoring and recording of the performance of all AFC equipment.

28. The station controller's office is equipped with public address, closed circuit television and other communications equipment and also facilities for monitoring the performance of all other electrical and mechanical equipment. The controller can also regulate the passage of trains to and from the adjacent stations in the event of a failure in the central control.

29. A small office is provided for the use of the Royal Hong Kong Police who have established a specially trained unit to police the railway. At Tsim Sha Tsui, Admiralty and Chater stations there are police reporting centres open to the public.

30. Staff locker rooms, toilets and a rest room are provided at each station according to forecast numbers of staff. A cleaners' room and refuse stores are also provided. There are no public toilets since the average journey time is less than 15 min and the maximum 28 min. Special facilities are provided at selected stations for maintenance staff and train crew.

E & M plant and equipment

31. Space has to be provided at each station for a considerable quantity of electrical and mechanical equipment. Dust-free, air conditioned rooms for signalling and communication equipment are provided at each end of each platform. At each end of each station there is an electric substation, where the 11 kV ring main supply is stepped down to 3 phase, 415 V for the operation of all the station equipment.

32. Sumps are provided at each end of each station from which any water entering the system is pumped to the surface. Foul water sumps are provided at the station end where the staff toilets are located.

33. The equipment which requires most space is that for the environmental control system. The underground section of the system is entirely air conditioned during the summer months. Cooling on the northern part of the system is by means of evaporative cooling towers mounted on the vent shafts. From Argyle station southwards cooling is provided by a fresh water closed pipe circuit with heat exchangers at sea water intakes on the waterfront.

34. Figure 15 shows the arrangement of the ventilation ducts in the public areas and the air flow patterns. The extract grills on the overtrack duct are located so as to extract the hot air directly from the air conditioning condensers on the trains. The underplatform ducts draw the hot air from the motors and other equipment under the floor of the cars. Conditioned air is also supplied directly to the tunnels at each end of the station and there are draft relief passages at each end of the station connecting the incoming and outgoing tunnels to reduce the train-induced draft at the end of the platform

35. The whole of the station area is equipped with fire detection circuits. In public areas, hose reels and hydrants are provided but there is no automatic fire-extinguishing system nor is there any audible alarm. There are hoses stored at each end of the platform adjacent to stopcocks which activate fire mains and hydrants in each tunnel. All plant rooms and the refuse stores are equipped with fully automatic fire-extinguishing systems using BTM gas. In the event of a fire in the stations, the air supply systems are closed down and the ventilation operates in extract mode only with bypasses to exhaust the smoke through vent shafts. The exhaust can be

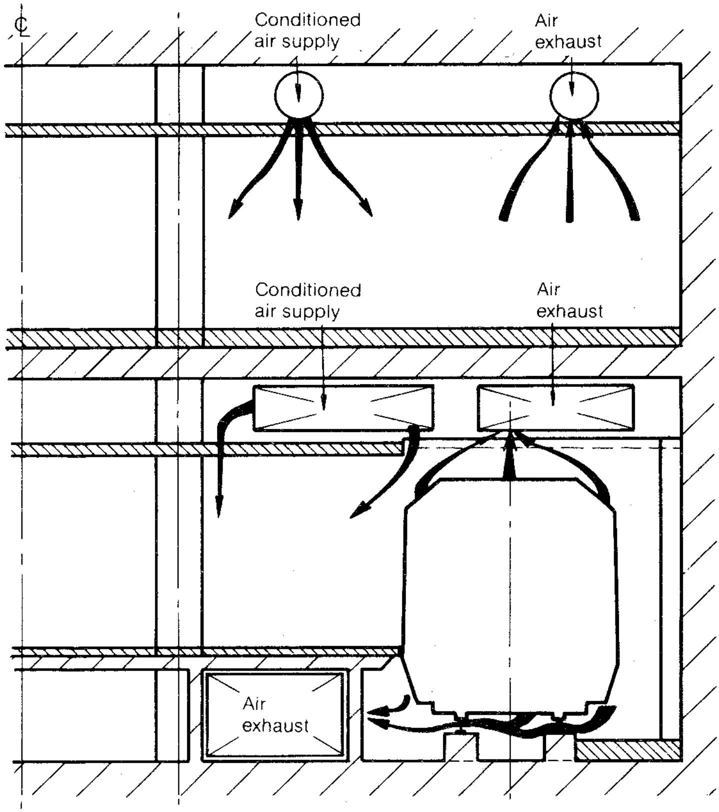


Fig. 15. Ventilation system

Table 2. Track alignment standards

Horizontal curves:	
desirable minimum radius	350 m
absolute minimum radius of running lines	200 m
absolute minimum radius in depots	140 m
absolute minimum radius in stations	1000 m
Vertical curves:	
desirable minimum radius	3000 m
minimum radius (near stations only)	1500 m
Gradients:	
absolute maximum	3·0%
minimum (for drainage)	0·3%
at platforms in stations	Level
Cant:	
desirable maximum	130 mm
absolute maximum	150 mm
Cant deficiency maximum	110 mm

reinforced by emergency fans. The effect of operating in exhaust mode only is that the entrances become the only source of supply air and thus air is drawn down to platform level, keeping all escape routes free of smoke.

Architectural finishes

36. The main criteria considered in the selection of finishing materials in the station were availability, visual appearance, choice of colours, ease of cleaning and maintenance, combustion and emission of toxic fumes and smoke, and cost.

37. Terrazzo tiles were selected for all public area floors except the platforms of overhead stations where pressed cement tiles were chosen since terrazzo becomes slippery when wet. Vinyl asbestos tiles are used in the offices and granolithic screed in the plant rooms.

38. For the long side walls of the underground concourses, a vitreous enamel panel system was adopted which is designed to incorporate internally illuminated advertisement panels. An applied finish is not suitable since the walls are not waterproof. The cladding system chosen has a wide choice of colours and is demountable to permit inspection and maintenance of the structure. The external wall at platform level remains exposed, though partially hidden by advertisement panels. At overhead stations the concourse wall is generally glazed. Mosaic tiles were used on all internal walls and columns and in entrances. Internal walls in the staff areas were rendered and painted.

39. For underground stations an aluminium louvre ceiling was chosen which conceals the services above from casual observation but permits inspection. For overhead stations the louvre ceiling was considered to be unstable in high winds and a slatted ceiling was chosen. Mineral fibre ceiling tiles were used in the offices.

Station structures

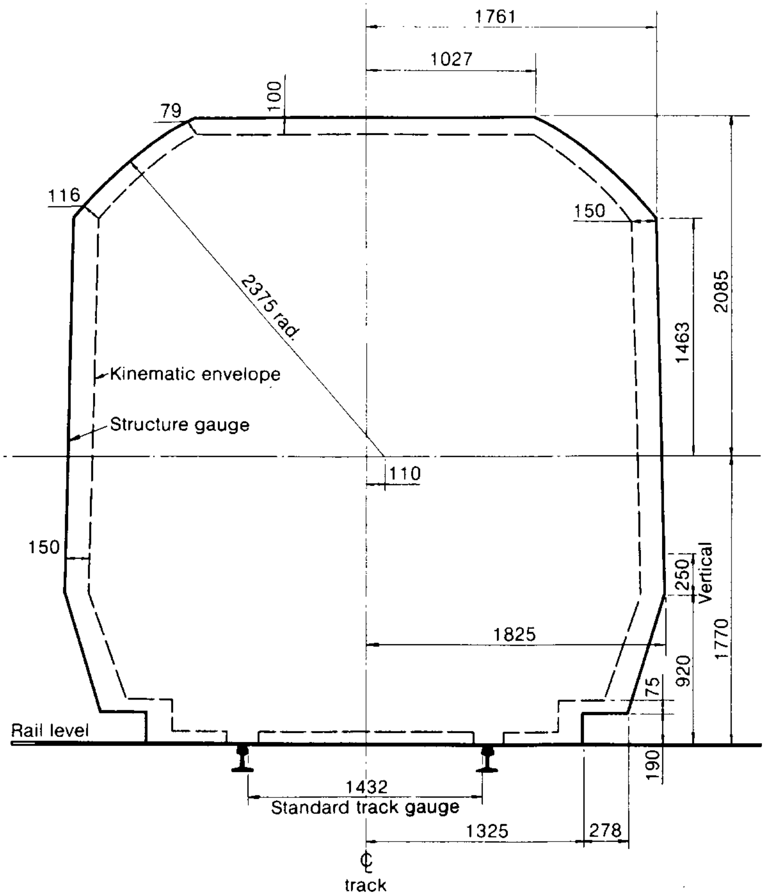
40. Most underground stations have been designed on the same structural pattern (Fig. 12). Two rows of columns at the rear of each platform are spaced to enable the escalators to fit between them. The column spacing of 8·4 m along the length of the station was selected so that an escalator would fit in two bays and the space between columns elsewhere would be ample to allow easy passenger circulation. Beyond the end of the platform the columns were located adjacent to the track to provide the least obstruction of platform level plant rooms.

41. To keep the depth of the station construction to a minimum, all the planning of the station was carried out on the basis of flat slab construction for the roof, concourse and base slab of the station. All main structural elements for the underground stations were designed to provide a 4 h fire resistance period.

Alignment

42. The system is designed to operate at a maximum speed of 80 km/h and the signalling system has normal operating speed codes of 40 km/h, 65 km/h and 80 km/h. In the depot speeds are restricted to 15 km/h. The basic alignment standards given in Table 2 were designed around the speed codes in that trains can operate at 80 km/h on a 350 m radius curve with 150 mm cant while the absolute minimum radius on running lines allows a speed of 40 km/h.

43. The speed codes were also used in the selection of four standard turnouts for



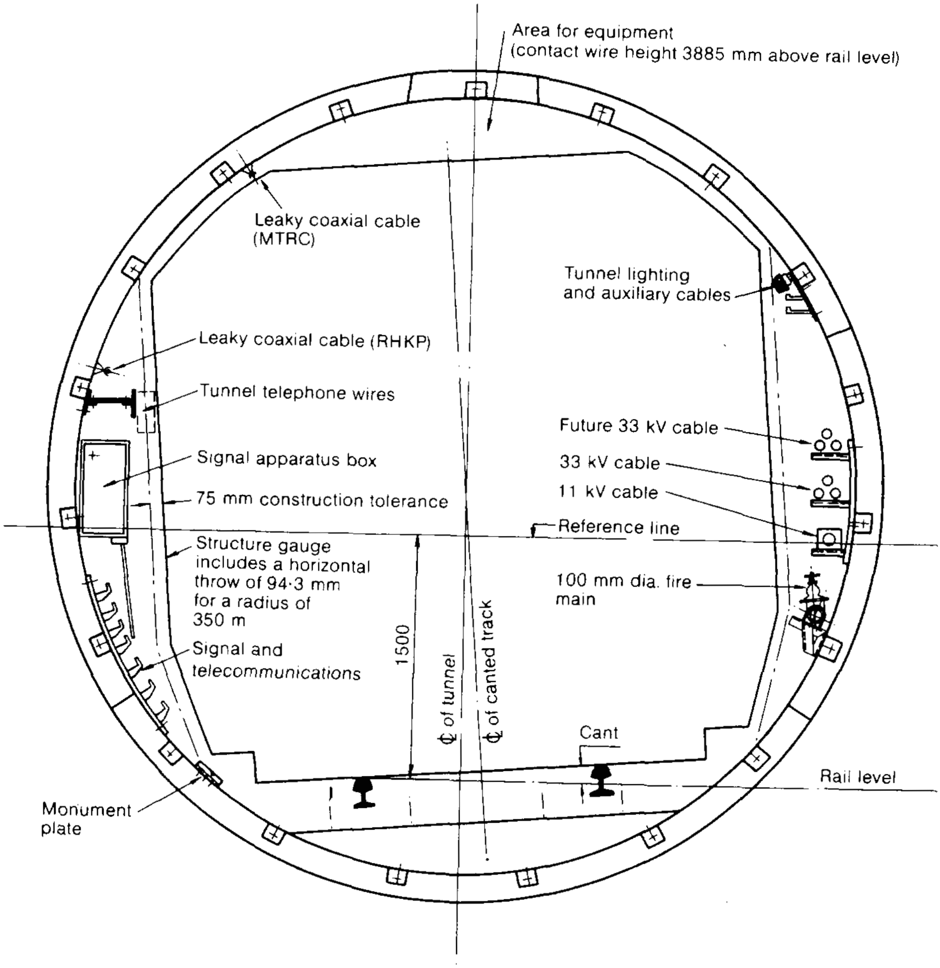
(a)

Fig. 16 (above and right) (dimensions in millimetres). (a) Kinematic envelope and structure gauge; (b) typical tunnel cross-section

use in the system. Turnouts with angles of 1 in 7, 1 in $10\frac{1}{2}$, 1 in 14 and 1 in 18 permit speeds of 30 km/h, 40 km/h, 65 km/h and 80 km/h respectively.

Tunnels

44. The tunnels were designed to accommodate the structure gauge (Fig. 16(a)) and much electrical and mechanical plant and equipment. Bored tunnel methods were chosen for most sections of the line between stations and a tunnel size was selected which after due allowance for construction tolerance could accommodate the tightest horizontal and vertical radius normally permitted on operating track. Part (b) of Fig. 16 illustrates how the gauge and E&M plant are accommodated in a typical tunnel.



(b)

Viaducts

45. Various methods of construction were considered for the elevated viaduct structures between stations. Prestressed concrete was selected on grounds of cost and also because the economic span range provided sufficient flexibility in the location of columns to cater for most situations on site. The appearance of the structure was also an important consideration.

Geotechnical

46. Hong Kong soils are primarily the result of in situ deep tropical weathering of igneous rocks, the commonest of which is granite. The weathering process yields fissures, friable rock, and coarse and fine sand, often mixed and changing in

Table 3

	Contract	Local (L) or overseas (O)	Contractor
101	North Nathan Road stations	O	Gammon, Kier, Lilley
102	South Nathan Road stations	O	Nishimatsu
103	Immersed tube	O	Kumagai (Japan)
106	Island stations	O	Metro Joint Venture
107	North Nathan Road tunnels	O	Gammon, Kier, Lilley
108	South Nathan Road tunnels	O	Nishimatsu
109	Tsim Sha Tsui and island tunnels	O	Aoki
201	Lok Fu station and Lok Fu to Diamond Hill tunnels	O	Metro Joint Venture
202	Shek Kip Mei station and tunnels	O	Maeda
203	Shek Kip Mei to Lok Fu tunnels	O	Kumagai (Japan)
204	Wong Tai Sin station	L	ICOS/Hip Hing
205	Kowloon Tong station	L	Kumagai (HK)
206	Choi Hung station	L	Paul Y
207	Diamond Hill station	L	Paul Y
208	Choi Hung to Kowloon Bay tunnels	L	Paul Y
209	Diamond Hill to Choi Hung tunnels	L	Paul Y
210	Kowloon Bay station and line sections	L	John Lok
211	Ngau Tau Kok station and line sections	L	Hip Hing
212	Kwun Tong station and line sections	L	Far East Engineering/Coignet
602	Kowloon Bay Depot foundations	Open	Mitsui
603	Kowloon Bay Depot podium	L	Paul Y
604	Kowloon Bay Depot ground level works	L	Paul Y
803	Trackwork	O	Henry Boot, Gammon

sequence frequently. The end product which penetrates to 30 m or more is, in engineering terms, a sandy silty clay. Within this weathered material, bodies of granite unaffected by the weathering process remain as isolated boulders (core stones) of very hard rock.

47. Until about a century ago much of Hong Kong was fringed by soft compressible marine deposits produced by local erosion or derived from estuarine sediments of the Pearl River. Since then off-shore reclamation has taken place at an increasing rate round the island and the mainland and much of the dense urban development is on this reclamation. A considerable part of the MTR, particularly on the island and at Waterloo and Argyle, had therefore to be constructed within these reclaimed areas.

48. Ground conditions vary considerably and abruptly along the route, a typical sequence of deposits being fill deposited for reclamation underlain by marine deposits, which are in turn underlain by weathered granite containing random boulders, the whole sequence being underlain by hard granite. Preliminary site investigation carried out at Further Studies stage enabled basic decisions to be made regarding tunnelling, station construction and harbour crossing methods. Data for structural design was obtained from the detailed site investigations carried out in 1973 and 1974.

Type of contract

49. The basic planning work to identify the size of the stations and establish the basic methods of construction was carried out in 1973 and 1974. When the Japanese consortium withdrew in January 1975, it was decided to proceed with invitation to tender on a multi-contract basis. A vital factor in this decision was the selection of the type of contract.

50. The type of contract had to enable construction to be completed as early as possible in order to start earning revenue and so reduce interest charges and ensure the financial viability. An added benefit of an early start was that advantage could be taken of a world-wide recession in the construction industry. Also, since the project had to be commercially viable, it was necessary to ensure that costs could be controlled and that the spiralling costs frequently associated with projects of this nature could be avoided.

51. The basis of the conditions of contract were the FIDIC, Civil and E&M conditions, with some amendments to incorporate some of the ICE 5th edition conditions and the Hong Kong Public Works Department conditions. Amendments were also made to take account of the fact that the Employer provided the insurance cover. The major contracts for the underground works were let on the basis of the contractor completing the design by preparing working drawings from the detailed general arrangement tender drawings issued by the Engineer ('contractor's design'). This achieved the objective of speed by avoiding the need for the Engineer to prepare working drawings at time of tender ('Engineer's design'). A contractor's design could also take advantage of his preferred method of construction and available plant so as to offer a lower tender sum.

52. The contracts for the elevated section of the railway were let on the basis of Engineer's design for a number of reasons:

(*a*) to ensure visual compatibility of the structure throughout;
(*b*) to widen the field of local contractors who could undertake the work since few had any design capability in prestressed concrete;

(*c*) the lead time necessary for Engineer's design was available in view of the shorter construction period required for above-ground structures.

The contracts for Kowloon Bay Depot were also let on the basis of Engineer's design but in this case because the programme required construction to start in some areas before the design requirements for other areas had been defined.

53. The objective of price control was achieved by letting all contracts on a lump sum basis. The measurement, whenever practical, was of activities covering

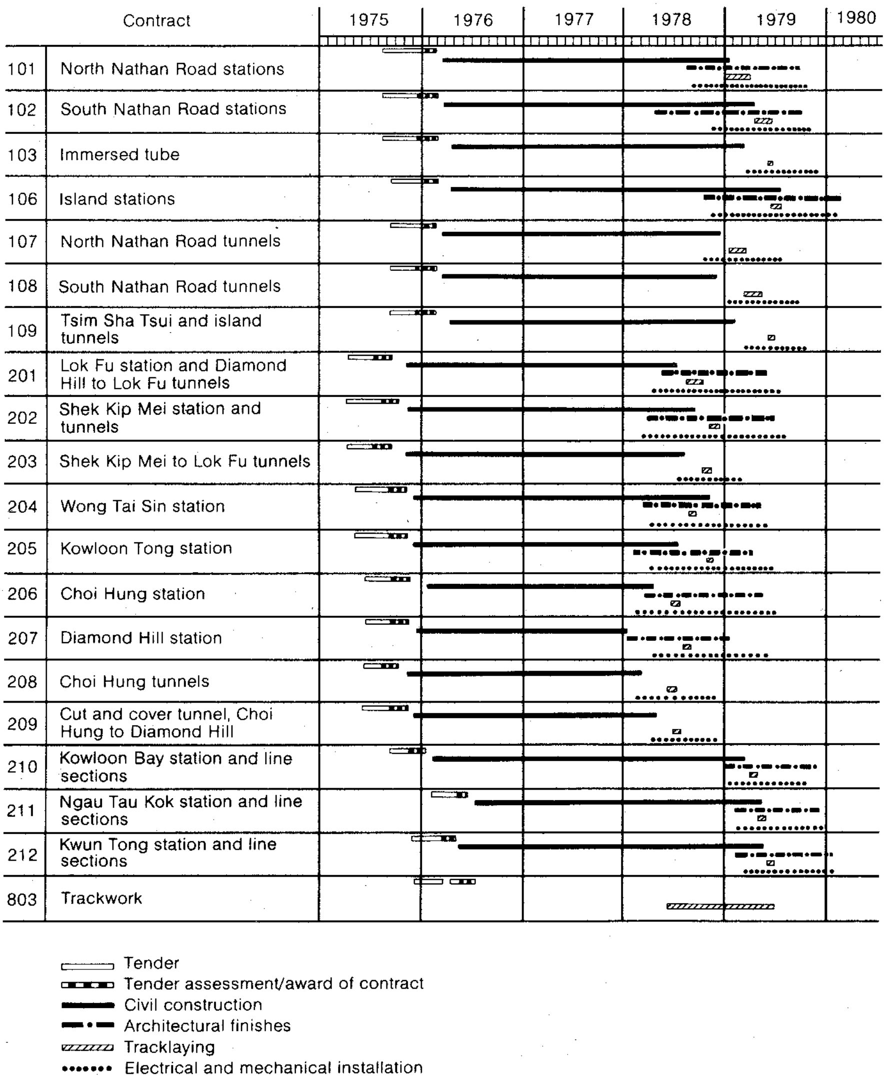


Fig. 17. Tendering and construction programme

relatively large discrete sections of work each priced as lump sums, which reduced work in interim valuations. Contractors had the option of including a clause making provision for escalation payments for civil works by use of special indices derived from local costs of labour and materials. Of the 23 major civil contracts, nine included provision for escalation.

54. The contractor was required to include for unforeseen natural ground conditions in his main tender. However, the contractor had the option of including an alternative clause covering 'unforeseen ground conditions' (based on clause 12 of the FIDIC conditions 3rd edition) under which he could offer a lump sum reduction in his tender; 20 of the major contracts included this alternative clause. Provision was also made in the contracts for contractor finance.

55. The extent of the works for the underground contracts was specified by means of general arrangement drawings which defined the structural outline, including major holes in slabs for ducts and cables. The electrical and mechanical layouts on which the drawings were based were very preliminary since no detailed electrical and mechanical design was possible in the very limited time between the withdrawal of the Japanese consortium and the issue of civil tender documents. In any event the electrical and mechanical contracts were also contractor's design contracts and were not due to be awarded until after award of the major civil contracts. The most significant electrical and mechanical contract in terms of civil interface, namely the contract for the environmental control system, was not awarded until November 1976. There was, however, provision in the civil contracts for the revision of the general arrangement drawings during the course of the contract to take account of revisions in the electrical and mechanical requirements.

56. The contract also specified the codes and design loads for the design of the structures and the standards for materials and workmanship. All drawings had to be approved by the Engineer.

Contract split

57. In determining the number and size of the contracts it was necessary to strike a balance which would encourage the participation of overseas contractors in difficult areas where their expertise was considered essential and yet enable local contractors to participate in the project. Account was taken also of the type of work so that contractors could make economic use of expensive items of plant such as tunnelling shields.

58. The balance between local and overseas contracts had to take contractor's finance into consideration since this would normally be available to overseas contractors through the export credit facilities provided by most governments but could not normally be provided by local contractors.

59. The split of work on the major contracts between overseas and local contractors is shown in Table 3. The estimated average value of the local contracts was about half that for the overseas contracts. Also, all the local contracts were for above-ground works or for underground works in North Kowloon where the ground conditions were better, and where there was likely to be less difficulty with traffic or utilities. Contracts for the more difficult construction on Hong Kong Island and in Nathan Road were tendered only by overseas contractors.

60. The whole success of the MTR project could be jeopardized by the failure of one contractor to meet the programme. For this reason all prospective tenderers, both local and overseas, were required to submit both technical and financial data to enable them to be prequalified for specific contracts. Where tenders were

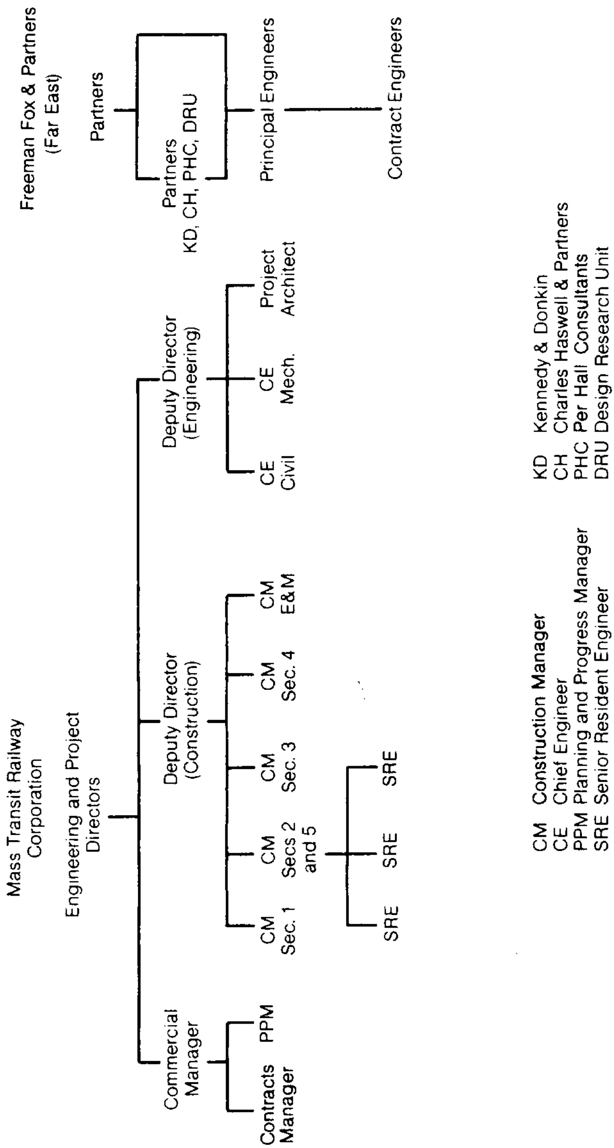


Fig. 18. Construction organization

submitted on a joint venture basis, all parties to the joint venture were required to provide a joint and several guarantee. Where appropriate a guarantee was also required from the parent company.

Cost estimates and viability

61. When the Japanese consortium withdrew and it was decided to invite tenders for the MIS on a multi-contract basis, it was appreciated that the viability of the project was dependent on the validity of the cost estimates. Thus, before a final decision to proceed with construction was taken it was necessary to confirm their validity. The first contracts were due to be awarded at the end of October 1975 and by this time tenders had been received for nine contracts, namely 201–209. The sum of tender prices for these contracts was adequately below the consultant's estimates and thus the Government and the Mass Transit Railway Corporation could, with confidence, take the decision to proceed with the project.

Tender and construction programme

62. The tendering and construction programme for the MIS is shown in Fig. 17. The installation of the track and of the electrical and mechanical equipment in the

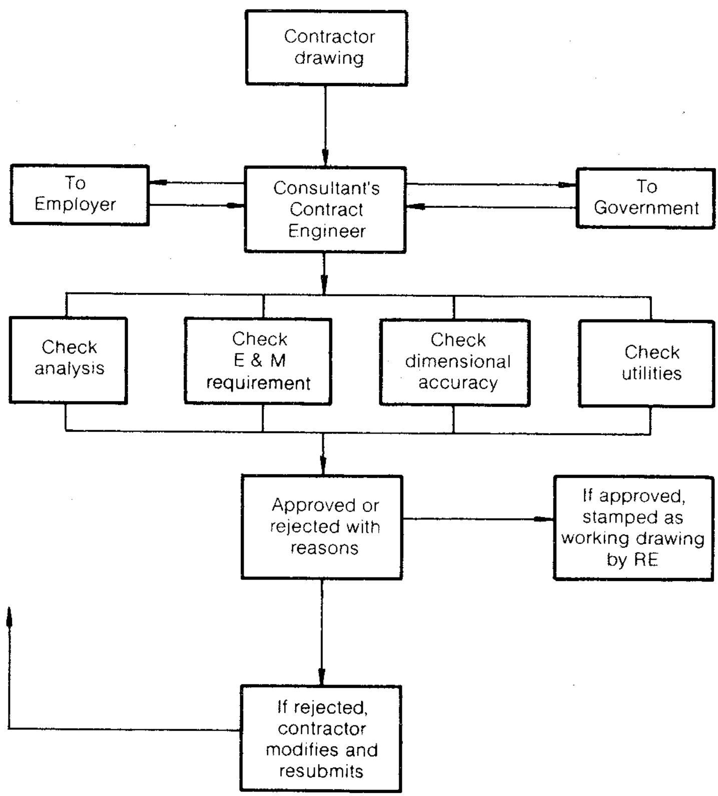


Fig. 19. Approval of contractors' working drawings

tunnels was programmed to be carried out sequentially from Kowloon Bay Depot. The whole programme was therefore designed around the estimated rate of laying the track and critical dates were specified in each contract by which the main contractor had to provide access to the track-laying contractor; these dates were subject to liquidated damages. Other critical dates were established in each contract for completion of plant rooms, offices etc. to enable electrical and mechanical contractors to install their equipment.

63. In practice of course the critical dates were not always met but one of the major features of the project has been the readiness of all contractors to co-operate in the implementation of contingency plans to obviate delays.

Construction organization

64. In order to generate revenue as early as possible the programme allowed a construction period of four years to opening the first section of the MIS. In view of the importance of meeting this programme within budget, the Corporation retained the management of construction in its own hands and set up an engineering and project team for this purpose. The Corporation's Engineering Director was nominated as the Engineer under the various contracts. Administration of groups of contracts was delegated to Construction Managers and Senior Resident Engineers. Within this overall management context the supervision of the immersed tube and depot contracts was delegated to the consultants (Fig. 18).

65. The checking of contractors' designs and approval of working drawings for contractor-designed contracts was also delegated to the consultants and was undertaken through consultant's Contract Engineers in liaison where necessary with the Corporation's engineering staff. Fig. 19 indicates the procedure adopted for approval of working drawings.

66. The speed of construction necessitated close co-operation between the Corporation and its consultants. There were regular formal meetings at all working levels and daily contact ensured proper co-ordination and progress of the project.

Acknowledgement

67. The Authors of this and the following three Papers wish to thank their colleagues who have assisted in the preparation of the papers and the Hong Kong Mass Transit Corporation for permission to publish them. The opinions expressed are those of the Authors and not necessarily of the Corporation or any other organization.

68. The Authors of the four Papers represent just a few of the many organizations which have contributed to the success of the project. A full list of these organizations would be too long to produce here. However, the Authors would like these Papers, which cover only some aspects of this project, to serve as an indication of the considerable efforts of all the organizations and individuals involved within the engineering disciplines and all other fields.

Reference

1. EDWARDS J. T. Planning and design of the Hong Kong Mass Transit Railway. *Proc. Instn Civ. Engrs*, Part 1, 1976, **60**, Feb., 9–26.