Design management for Hong Kong Metro

IIIc

Design Management for Hong Kong Metro

Direction de projet pour le métro de Hong Kong

Entwurfsleitung für die Hong Kong Metro

JAMES EDWARDS
Dr. Eng.
Freeman, Fox & Partners
London, England

SUMMARY
Design of the Metro system involved civil, electrical and mechanical engineering requiring several consulting engineering firms who were engaged under the overall direction of the Principal Consultant. Civil engineering contracts for the underground works made the contractor prepare the detailed working drawings. These conditions created the need for close management of design.

RESUME
Le projet du système du métro de Hong Kong a nécessité la collaboration de plusieurs bureaux d'ingénieurs-conseils, spécialistes en génie civil, en installations électriques et mécaniques. Ces bureaux ont collaboré sous la haute direction d'un bureau d'ingénieurs-conseils principal. Les contrats de génie civil attribuaient à l'entrepreneur le projet de détail pour les travaux souterrains. Ces conditions ont rendu nécessaire une ferme direction du projet.

ZUSAMMENFASSUNG
Entwurf und Projektierung der Untergrundbahn in Hong Kong stehen unter der Gesamtleitung von einer hauptberatenden Ingenieurfirma. Die Projektierung eines grossen Untergrundbahnsystems erfordert eine Anzahl qualifizierter Ingenieurunternehmungen für die Behandlung der speziellen Probleme im Bereich Bau, Elektro und Maschinen. Die Erstellung der Detailpläne für die Tiefbauarbeiten wurde gemäss Verträgen den ausführenden Bauunternehmungen übertragen; die daraus resultierende enge Zusammenarbeit machte eine entsprechend starke Leitung der Projektierung notwendig.

1. OUTLINE OF THE PROJECT DESCRIBED IN THIS PAPER

The Project to which the Design Management procedure described in this Paper applies is the Modified Initial System (MIS) of the Hong Kong Mass Transit Railway. The System comprises 12.8 route - km and 12 stations underground and 2.8 route - km and 3 stations elevated. It runs as shown in Figure 1 from the Central District on Hong Kong Island to Kwun Tong in the north-east of the built-up area of Kowloon on the mainland. When other lines and extensions have been completed the trains, initially to be of 4 long, wide cars, will be formed of 8 cars having a crushload capacity of 3,200 and at the designed headway of 2 minutes able to carry 60,000 passengers per hour.

The stations having to be designed to handle up to 400,000 passengers per day, have required extensive research and careful design to enable that arduous duty to be met both economically and sufficiently attractively to draw such large numbers of passengers.

The Railway is being constructed and operated by the Hong Kong Mass Transit Railway Corporation (referred to below as the Employer) which was established for this purpose in 1975 replacing earlier temporary bodies.

Construction commenced in November 1975 and the first part of the line was open to public service in Autumn 1979. The whole MIS should open in 1980 soon after this Congress. Construction of the Tsuen Wan Line was started in 1978 but the management of its design differs from that described in this Paper.

2. SPECIAL FEATURES OF THE PROJECT AFFECTING DESIGN MANAGEMENT

The parties to some design decisions may include not only the Consultant and the Employer but in the case of Hong Kong Metro, the Contractor, numerous Government Departments and public utility companies. This Paper cannot cover all aspects but concentrates on the Consultants' viewpoint.

The Principal Consultants are Freeman Fox & Partners (Far East) who have engaged the following associated firms in the fields stated: -

Kennedy & Donkin	- Electrical & mechanical engineering
Charles Haswell & Partners	- Bored tunnels
Per Hall Consultants Ltd	- Immersed tube tunnels
Design Research Unit	- Architecture and industrial design
London Transport International	- Metro management and operation

A simplified relationship between these firms is shown at Figure 2. When, however, the relationship is set out by specialist technical activity as in Figure 3, the complexity becomes much greater and the need for co-ordination and management of design readily apparent. Even so that diagram shows only the specialists involved in the design and construction phases and not the earlier conceptual design phase.

Whereas the designing of metros has much in common with other large scale projects such as electricity generation and chemical plants in that civil, electrical and mechanical engineering are interwoven, the requirements of operating the project, which affect design, are fundamentally different. The flow of passengers might be considered a refined type of material handling problem corresponding to coal in an

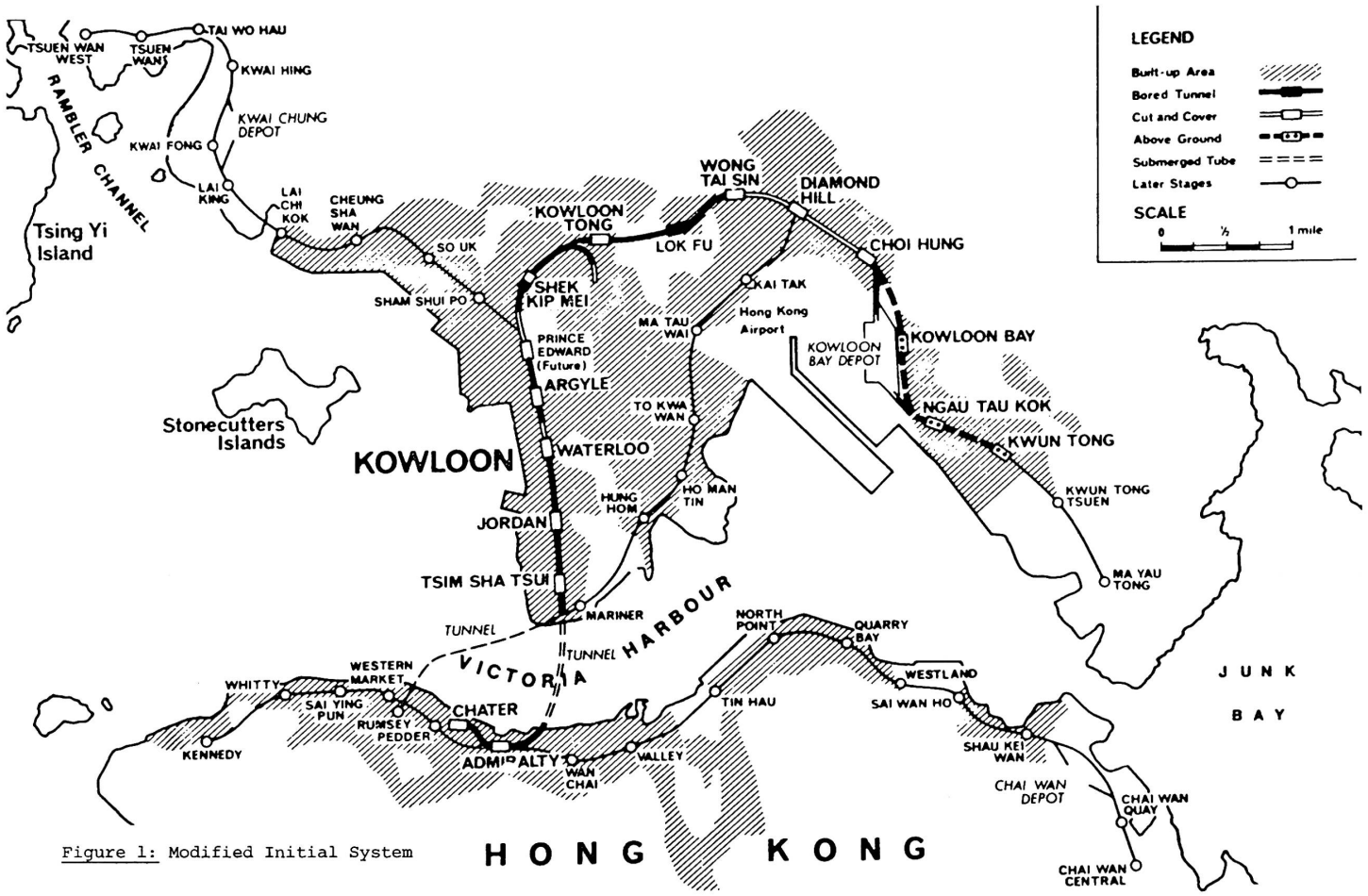


Figure 1: Modified Initial System

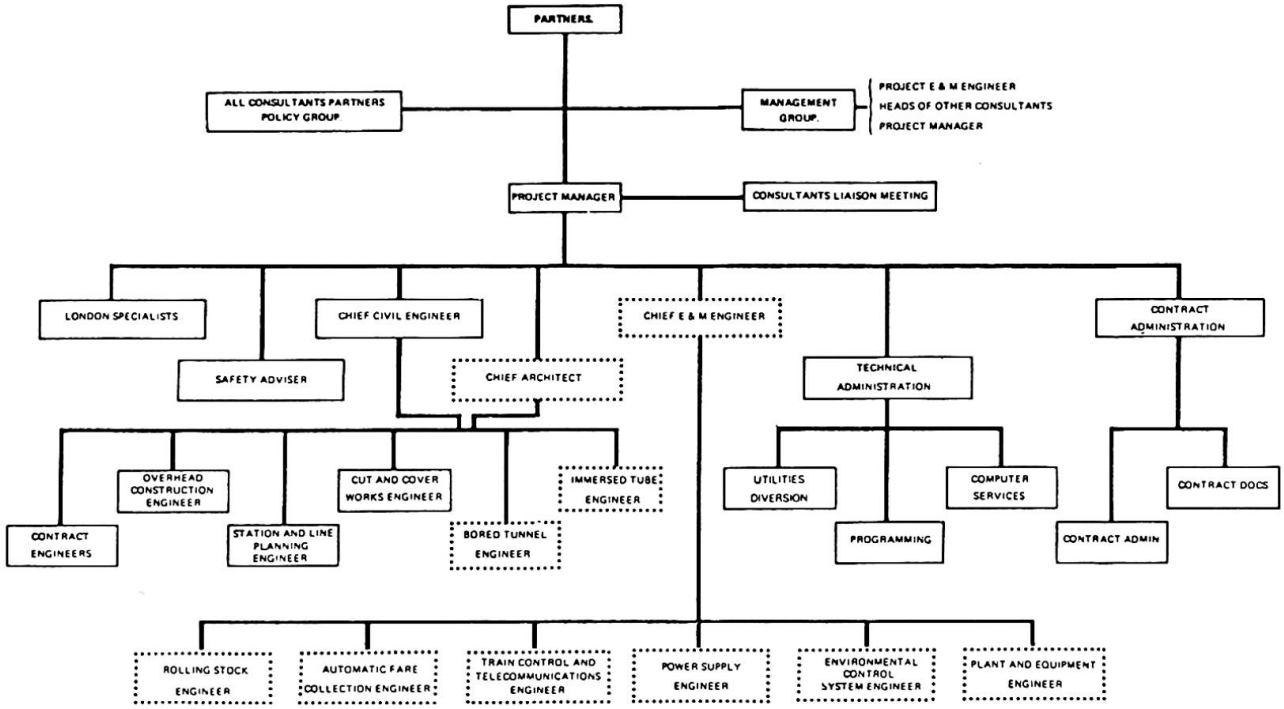


Figure 2: Consulting Engineer's Organisation

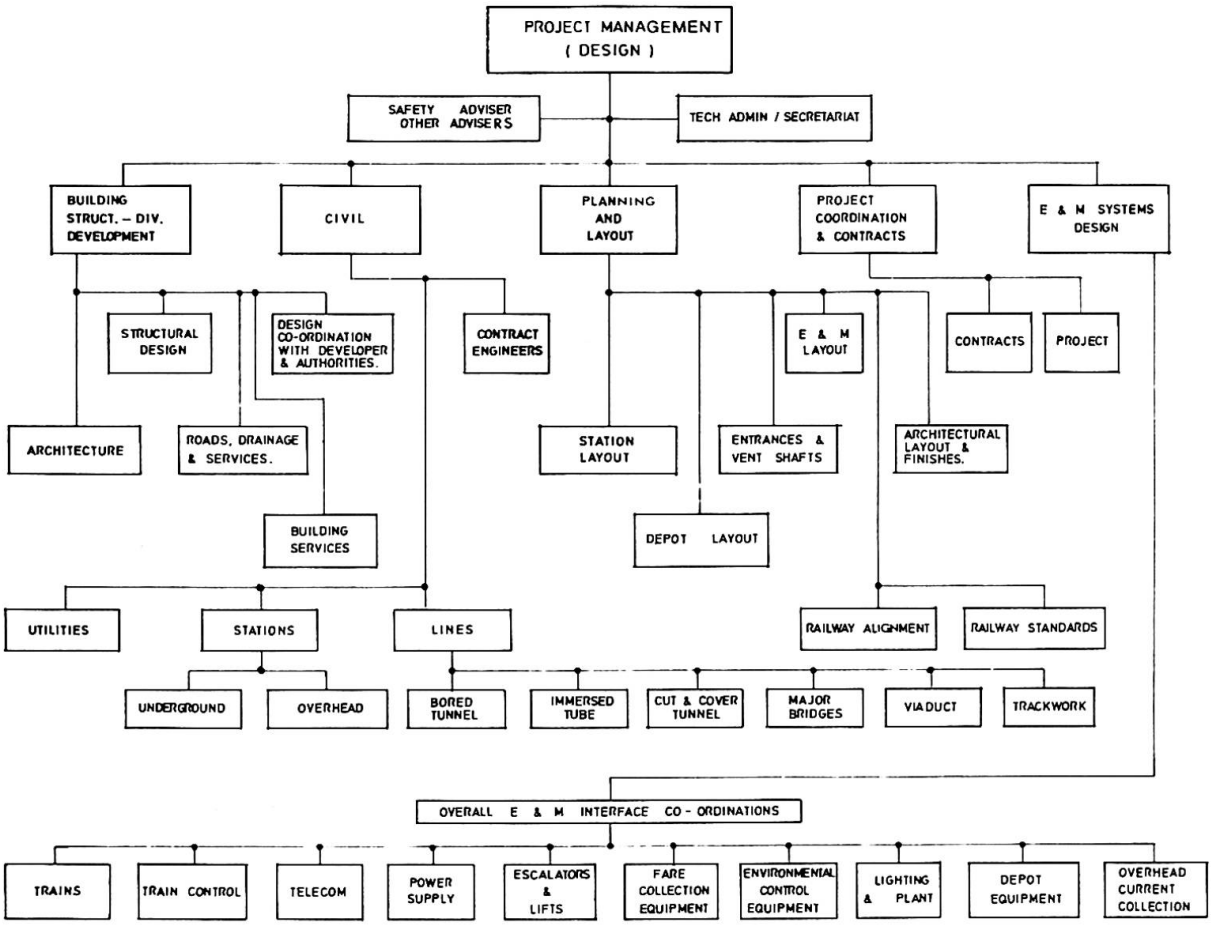


Figure 3: Project Management

electricity power station or chemicals in a plant. But the fundamental difference is that a designer can control the quantity of materials to be handled, but he must make a metro sufficiently attractive to draw the maximum number of passengers. This is desirable in any metro system for social reasons, but essential in Hong Kong where enough passengers have to be attracted to make the fare revenue sufficient to pay the whole capital and operating costs.

The number of metro passengers will be the maximum if the line and stations are located in the best places, the stations and trains are made attractive relative to other public transport and the fares are set as low as possible. These factors require the design team to include planners, transport economists and railway operators as well as engineers, thus increasing the complexity of design management.

Many branches of civil, electrical and mechanical engineering have to be applied to the design of a metro. In a new metro there is considerable freedom to apply the latest technology in the related electrical and mechanical engineering fields. This involves the evaluation of alternatives and the interaction between them. Civil engineering design of an urban metro is by that very feature of being urban, far removed from development on a "green field" site. If the railway is below ground the complexity of public utilities such as water, gas, electricity, telephone, radio pipes or cables and drainage of all types can have a major influence on civil engineering design. Major buildings in Hong Kong are generally on piled foundations which affect greatly the design of both adjacent cut-and-cover works and tunnels near or beneath buildings. The multi-disciplinary consequences of these factors are shown in Figure 4.

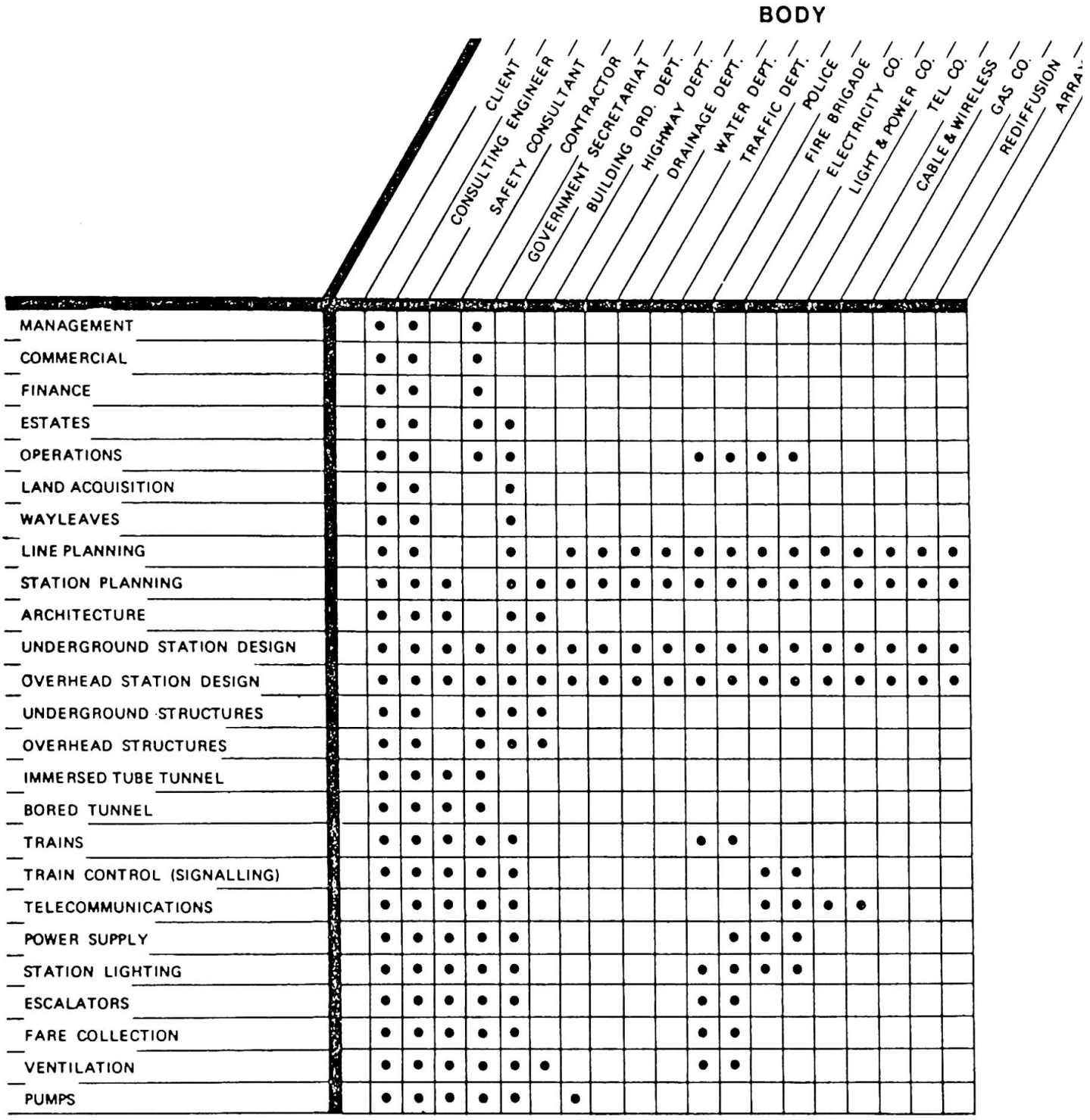
All these factors bear on design and in turn require the design management organisation to handle them effectively and expeditiously. The need for speed was of particular importance in Hong Kong since the requirement that the metro should finance both its construction and operation from fare revenue, made it imperative for revenue to be earned as soon as possible after capital expenditure commenced.

3. GENERAL PRINCIPLE OF DESIGN MANAGEMENT

The objective of design management is to produce good designs within the programme required for the construction of the project. These two requirements are often, perhaps usually, in conflict. Good designs, expecially for technologically advanced or unusual projects, require a length of time which may be difficult to forecast. If enough time is not allowed in the programme for the conception and development of design, then no amount of management effort made can prevent the project being in some degree a failure.

The design of Hong Kong Metro has always been carried out within a programme covering the whole design and construction period. The planning and monitoring of the programme has used the Consultants computer-based INTERNET program. The durations allowed for all design and construction activities have been carefully planned so that impossibly tight programmes were avoided where they could be foreseen. Nevertheless the programming of design is more difficult than construction. Even if design is running in accordance with a programme, the key work in conceptual or initial design may be in the hands of a single design engineer.

The Project Design Management was not only responsible for the direction and control of the design but involved in technical decisions. Whilst the latter role might be considered a normal position, it is often the case that the time of top



NOTE

1. ● indicates the Body is involved in the subject shown.
2. Neither the Bodies nor the Subjects are exhaustive.
3. The involvement shown is an indication and not intended to imply that other Bodies or Subjects are not involved.

Figure 4: The Multi-disciplinary Aspects of H.K. Metro

management is so taken up with attending meetings and handling paperwork that little time remains for the discussions with middle and senior engineers necessary to obtain the background for technical decisions.

Most of the design was in the hands of middle level engineers, who liaised with their opposite members in related fields by informal discussions over drawing boards as well as formal meetings. The contentious matters which arose, as well as policy, were dealt with at senior level often in step with the straightforward design, but inevitably at times under great urgency. It is folly to believe that by sufficiently detailed design planning, potentially difficult decisions can be identified and high-lighted well in advance of the time when a decision is required. It was recognised that there would always be a flow of decisions required at high level and the procedures used which were varied as the stages of the project changed, worked well.

The highest level at which design decisions were taken was the Chairman and Board of the Employer. During the main period of MIS design the usual upper level of decision on design was the Employer's Engineering and Operations Committee on which sat the Executive Directors, of whom the Engineering Director was the "Engineer" under the contracts, and the Consultants. The Committee was usually asked to approve papers prepared often jointly, by the Consultants or the Employer's staff on specific subjects. Only a very small proportion of design decisions were made at these upper levels.

The usual upper level for management of design was the partners of the consultant firms. Many decisions were also made in ad-hoc and formal committees or working parties. To give one example, a major area for design co-ordination was the layout of stations. For this purpose a Layout Co-ordination Group was formed staffed by engineers from the consultants with representatives from the Employer who worked out mutually acceptable solutions which were then binding on all parties (described further in Chapter 4).

The organisation of the Consulting Engineer below the level of the partners is shown in Figure 2. The posts were filled by Freeman Fox staff except those within the dotted panels which were filled by the associated consultants given above. The contributions by London Transport International, the planners and transport economists as well as acoustical, geotechnical and other specialist advisers, are included in the panel "London Specialists". Figure 3 shows many, but not all, of the fields of design covered by the men in these posts. No formal grouping of all these specialists into committees or working parties could cover the whole design field. The success of several firms of consulting engineers and many specialists working together on a complex project depends upon the integration of the staff of the individual firms into a single team. This has been achieved by the organisation and worked well. There have, of course, been instances of poor co-operation or co-ordination but such things occur occasionally in any large organisation. The important feature has been that as soon as such an instance occurs, there has been an organisation operating which can see, at an appropriate level, that the trouble is put right with a minimum of delay or friction.

The routine forum for the management of design was the Consultants Liaison Meeting (See Figure 2) chaired by the Consultant's Project Manager (a partner). Two such series of meetings were held; one for the design of Kowloon Bay Depot (a vast project with a "new town" for 25,000 people over it) and another for all other design matters.

The conceptual design was managed initially by regular monthly meetings of the Consulting Engineer's constituent firms with additional meetings, when required, devoted solely to a current major problem. After the establishment of the Mass Transit Railway Corporation, the development of the design involved the Consulting Engineer's staff working with its staff either as individuals or in committee.

The next stage in the development of the design covers the preparation of tender drawings. Some of the civil engineering contracts were conventional with all details being prepared by the Consulting Engineer. The majority of the principal contracts were based on very detailed general arrangement drawings being provided with the Tender Documents from which the Contractor was required to prepare his detailed working drawings to suit his approved construction methods.

The design development sequence is illustrated in Figure 5. Whilst the management of the steps in design are in general as already described, there are some situations where the management process becomes much more complicated. The co-ordination of civil, electrical and mechanical engineering details is the prime example.

Many of the conceptual design drawings of the civil engineering works are based on electrical and mechanical engineering details which, although conforming with the appropriate electrical or mechanical engineering contract specification, are not necessarily those required by the electrical and mechanical contractor to whom a particular contract is awarded. A vital aspect of design management is to ensure that E&M details are compatible with the civil engineering works and that the civil engineering details will be compatible with the E&M equipment when it is erected.

Figure 6 shows how the E&M contractor's proposals were appraised and approved. The approved drawings were then used by the civil engineering contractor to prepare his working drawings which, in turn, had to be submitted for approval. Before being approved they were checked by the Consulting Engineer to ensure that they would provide the requirements shown on the approved E&M drawings.

4. VARIATIONS TO SUIT PARTICULAR PHASES

Contracts for some major projects such as dams and highways can be let with full working drawings having been completed so that virtually no design drawings are issued during the construction phase of the project. This was not the case in Hong Kong Metro partly because of the requirement for the contractor to produce detailed working drawings and partly because of the need to modify the civil engineering design to suit the plant and equipment as manufactured. At the outset of the construction phase the contractor developed his working drawings based on his methods of construction and the tender drawings which prescribed the fully dimensioned envelope within which he had to design the civil engineering works. All critical clearances and dimensions were noted on the tender drawings and tolerances laid down in the specification. These tender drawings took full account of the requirements of the plant, drainage, services etc and inculded architectural general arrangement drawings and large scale typical details. Each contractor was required under the contract to produce a detailed drawing programme showing the timing and description of the drawings he had to prepare, related to his construction programme. This Drawing Submission programme, together with the consultant's response, were monitored twice each month and corrective action taken when required. The person responsible for the day to day management of design in this phase was the Consultant's Contract Engineer.

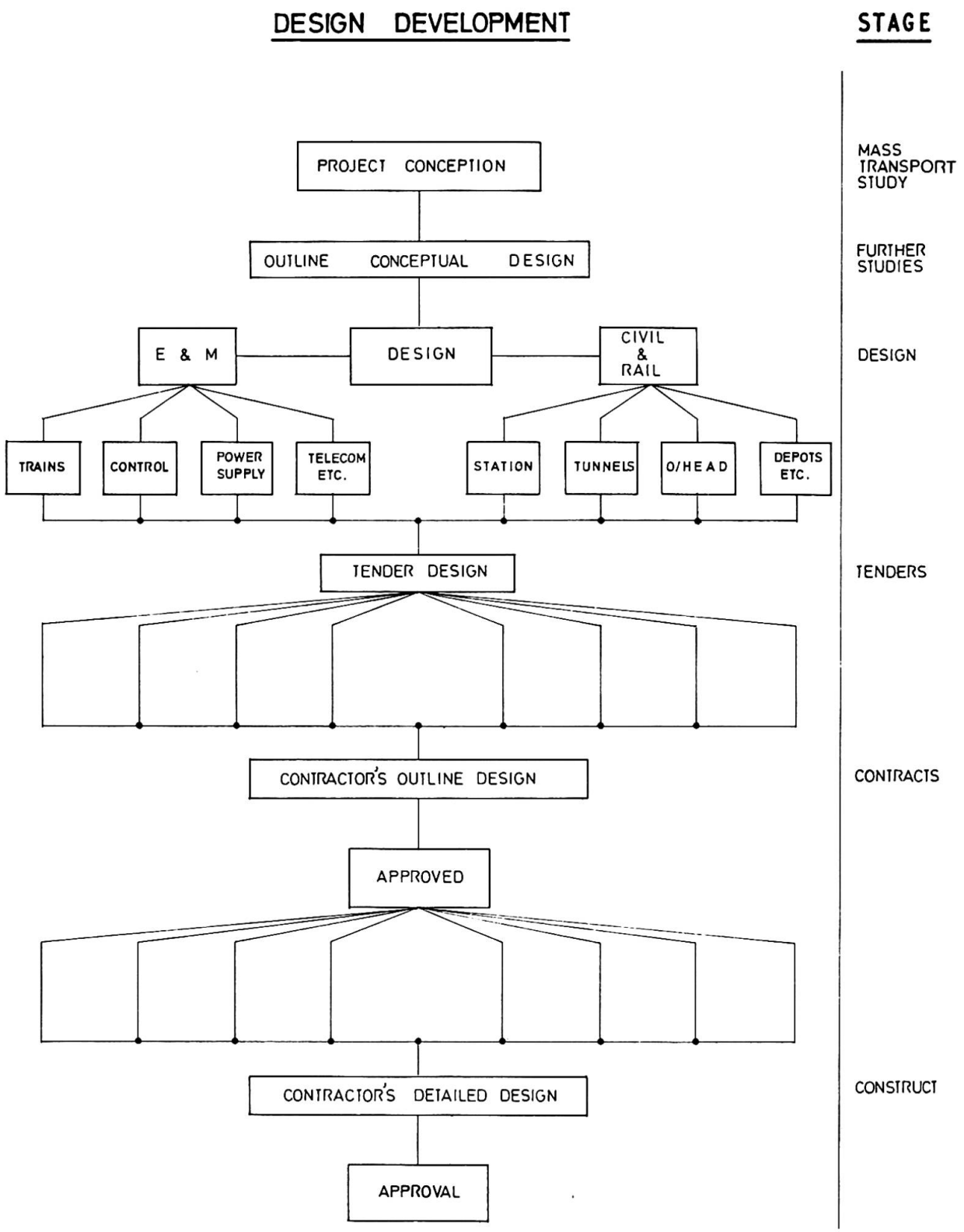


Figure 5: Design Development

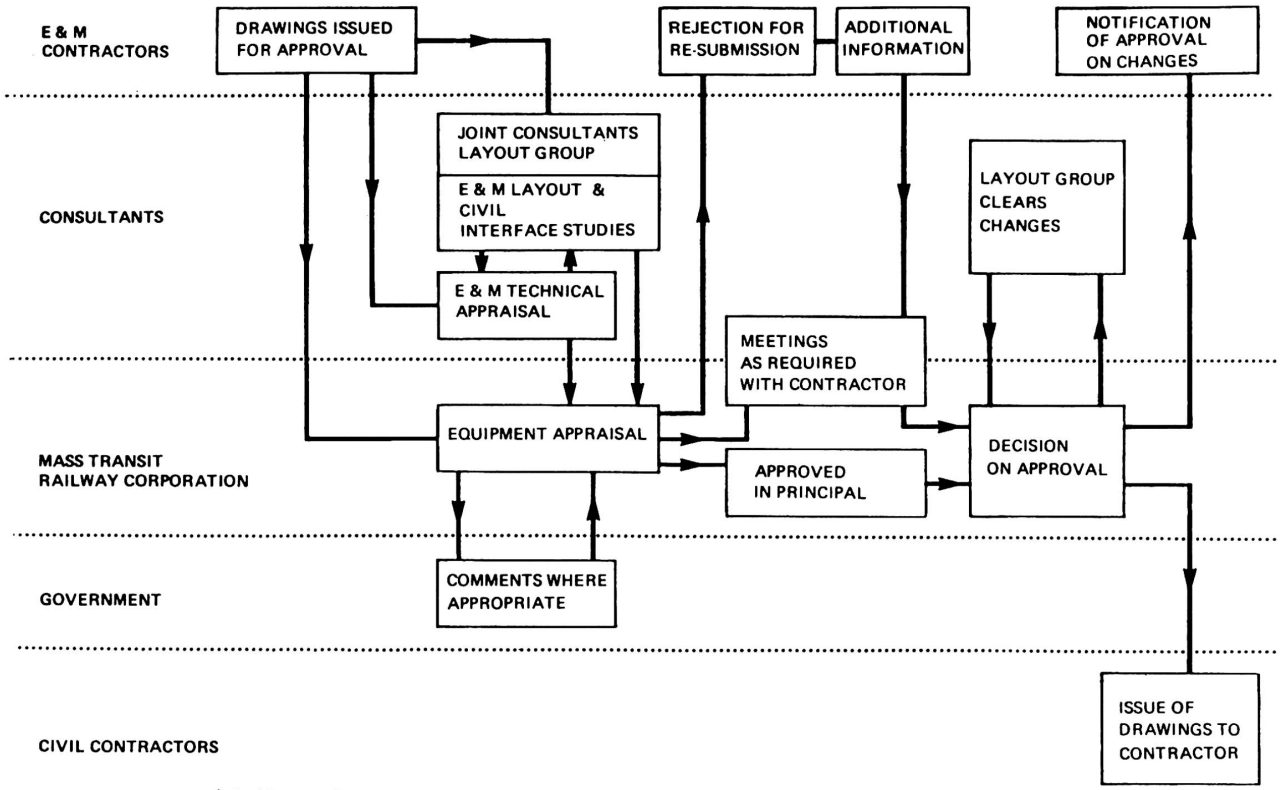


Figure 6: E & M/Civil Drawings

Consultant's Contract Engineer

The role of the Consultant's Contract Engineer is shown diagrammatically in Figure 7. Although his duties are administrative and he appears to act primarily as a post office, the duties can be discharged only by an engineer with good general experience and sound common sense. His prime duty was to ensure that the working drawings were on site to meet the construction programme. This required him not only to monitor that the drawing was prepared by the Contractor to programme but to know all the parties who had to approve or to check the drawing and make sure that they did it within the overall available time. A particular drawing may have to go through the process more than once because of either an unsatisfactory feature on the drawing requiring its resubmission or a change in requirements due for example to a change in plant or site conditions requiring amendment of an approved drawing. About 6,000 contractor's drawings were processed in this manner. A similar procedure was used to regulate the issue of about 1500 drawings to contractors working to the Engineer's design.

Layout Co-ordination Group

The purpose of this Group was to co-ordinate the requirements of many specialists to produce an optimum design. In tunnels this requires, for example, the cables, fire main and drainpipes to be located. In stations the arrangement of the many different types of plant and equipment in conjunction with provision of staff rest rooms, administrative offices and the most desirable passenger handling arrangements inevitably leads to conflicts of requirements. The Group contained representatives from all Consultants and the Employer who between them could discuss alternative arrangements with sufficient authority in their own field to enable a consensus decision to be reached. This procedure was difficult to programme effectively because the extent and seriousness of conflicts of requirements did not become apparent until details were developed. The Group did not have a Chairman-Dictator who might have speeded the process of initial agreement but that could have led to changes becoming necessary after an agreed arrangement was found to be unworkable. Any change to an approved drawing would have prejudiced the maintenance of the programme. Although this procedure appears to give haphazard control over the management of this phase of the design, the higher levels of management were always available, and used when necessary, to keep the design development in step with the overall programme.

5. CONCLUSION

The procedures outlined in this Paper were a major factor, although not of course the only one, in the construction of the first stage of the Hong Kong Metro within four years; one of the quickest built comparable railways. A similar procedure might be equally successfully applied to other large scale complex projects.

6. ACKNOWLEDGEMENTS

The opinions expressed in this Paper are those of the Author and not necessarily those of the Mass Transit Railway Corporation. The Author acknowledges gratefully assistance received from his colleagues D.A. Morris and D.F. McIntosh.

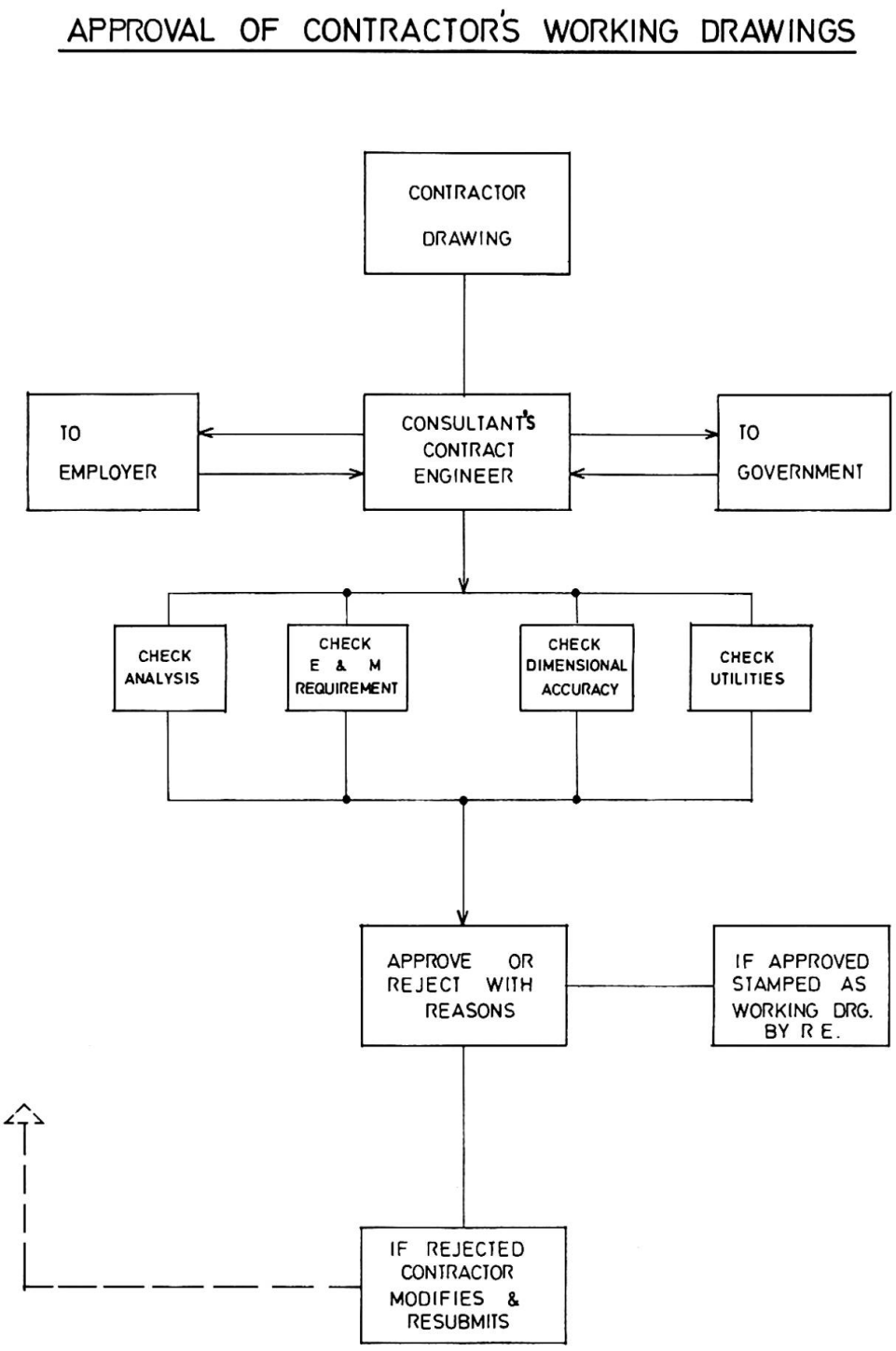


Figure 7: Approval of Contractor's Working Drawings