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III

Management in the Design and Execution of Important Constructions

Gestion du projet et de la construction de grands aménagements de génie civil

Management in der Planung und Ausführung grosser Bauvorhaben

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III

Einführung zum Thema

Introduction to the theme

Introduction au thème

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ZUSAMMENFASSUNG
Am Kongress sollen an Hand konkreter Beispiele realisierte Lösungen:
- für Entscheidungsvorgänge, die zur Wahl einer bestimmten Variante geführt haben
- für die Projektorganisation in der Planungs- und Ausführungsphase
- für die Budgetierung und Überwachung der Kosten in der Planung und Ausführung grosser Bauvorhaben

vorgetragen werden.
In den nachstehenden Berichten wird die Grundlage für eine anregende Diskussion gelegt.

SUMMARY
At the congress we would like to discuss papers which deal with realized examples of large and important constructions and to concentrate on:
- decision processes for the choice of a specific solution among several alternatives
- solutions for the organization of the design and construction process
- the budgeting and control of cost in design and execution.

The following reports provide the basis for an interesting discussion.

RESUME
Des exemples concrets de solutions réalisées pour de grands aménagements de génie civil illustreront:
- les processus de décision pour le choix d'une solution spécifique parmi plusieurs possibilités
- les solutions retenues pour la direction du projet dans les phases d'étude et d'exécution
- le budget et le contrôle des coûts dans la phase d'étude et d'exécution.

Les rapports présentés ci-après serviront de base aux contributions qui seront présentées lors du Congrès.

HAUPTPROGLEME

Wer die Kosten, den zeitlichen Verlauf des Entwurfs und der Ausführung sowie die Qualität von grossen Bauprojekten unter strenger Kontrolle halten kann, erfüllt die Anforderungen, die an ein modernes Management gestellt werden. Wir orientieren unsere Entscheidungen an den geplanten optimalen Kosten (OC) und der errechneten optimalen Projektdauer (PT), wobei wir die generelle Planung und die Betriebsphase des Bauwerkes nicht zur Projektdauer zählen wollen.

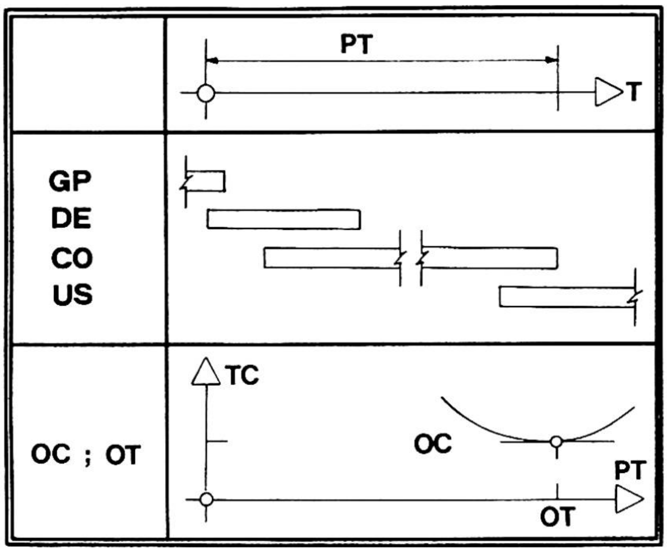

Bild 1: Optimale Projektdauer und Projektkosten

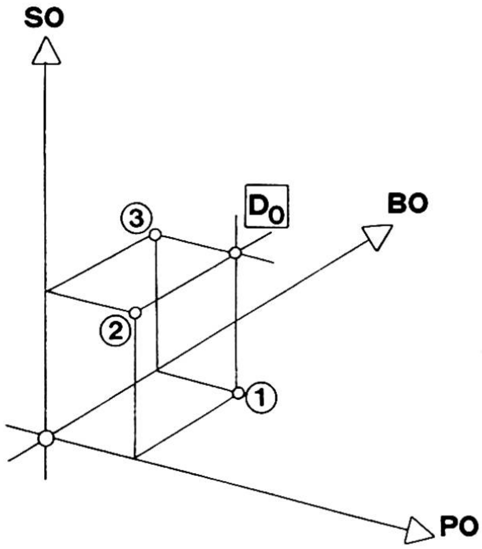

Bild 2: Entscheidungen und Organisationen

Zeitgerecht und sachlich fundiert zu entscheiden ist Hauptaufgabe der beteiligten Organisationen. Die Vielzahl der beteiligten Organisationen macht das Management im Bauwesen erst spannend, wobei im allgemeinen Fall für eine Entscheidung (D_O) nicht nur die Projektorganisation (PO), sondern meist auch die Basisorganisation der betroffenen Firma (BO) und in irgend einer Weise auch die Baustellenorganisation (SO) engagiert sind. Die Sonderfälle 1, 2 und 3 in Bild 2 stellen Entscheidungen dar, bei denen nur ein Teil der Organisationen engagiert wird.

Am Kongress in Wien möchten wir das gestellte Thema an praktischen Fällen behandeln und dabei drei Aspekte in den Vordergrund stellen:

- Gestaltung von Entscheidungsvorgängen an konkreten Bauvorhaben, die zur Wahl eines bestimmten Projektes, eines bestimmten Bauverfahrens oder eines bestimmten Planungs hilfsmittels geführt haben
- Gestaltung und Begründung organisatorischer Lösungen für die Bearbeitung der Planungs- und Ausführungsprobleme bei grossen Bauvorhaben
- Budgetierung und Ueberwachung der Kosten bei der Planung und Ausführung grosser Bauvorhaben.

Diese Probleme stellen sich bei allen Partner im Bauprozess, beim Bauherrn, bei den planenden Ingenieur- und Architekturunternehmungen, bei den leitenden und ausführenden Bauunternehmungen.

In den nachfolgenden Beiträgen werden die Hauptprobleme dargestellt, damit entsteht eine breite und anregende Grundlage für Kongressbeiträge. Am Kongress sollen an Hand konkreter Beispiele die tatsächlichen Lösungen zur Darstellung kommen, wobei die kritische Analyse der Lösung Bestandteil des Beitrages sein muss.

IIIa

The Importance of the Organization in the Design and Construction Process of Large Projects

Importance de l'organisation dans les phases d'étude et d'exécution de grands aménagements

Die Bedeutung der Organisation in der Planung und Ausführung von grossen Bauvorhaben

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SUMMARY
This paper gives an overall view on the nature of the organization of the design and construction process in large projects. The way to organize this process differs from country to country. The partners in the process form the organization. As the partners enter the organization at different points of time, close cooperation between them is necessary in order to arrive at the best solution within the desired time, cost and quality for a project. The method of selecting the different partners is of special interest; why do we select the construction partners in a different way from all the other partners?

RESUME
Ce rapport présente une vue d'ensemble de l'organisation dans les phases d'étude et d'exécution de grands aménagements. L'organisation varie d'un pays à l'autre, mais elle dépend essentiellement des différents partenaires qui en font partie. Ces partenaires entrent dans l'organisation à différents moments: une collaboration étroite est donc nécessaire pour atteindre l'objectif dans le délai, le budget et le niveau de qualité fixés. La méthode de choix de différents partenaires est d'une importance primordiale; la question est posée de savoir pourquoi le choix de l'entrepreneur n'est pas fait selon les mêmes critères que le choix des autres partenaires.

ZUSAMMENFASSUNG
Die Probleme der Organisation des Entwurfs- und Ausführungsprozesses bei grossen Bauvorhaben werden bearbeitet. Der Charakter einer Organisation für ein grosses Bauvorhaben ändert von Land zu Land, es sind die verschiedenen Partner, die die Organisation letztlich ausmachen. Der Zeitpunkt des Eintrittes eines Partners in eine Organisation prägt den Ablauf der Arbeiten, die Kooperationsfähigkeit der einzelnen Partner ist von entscheidender Bedeutung für das Resultat der Arbeiten. Die Methode der Wahl der Partner rückt deshalb in den Vordergrund, warum wählen wir eigentlich die ausführenden Unternehmer anders aus als die projektierenden Ingenieure?

1. INTRODUCTION

Time and again it is necessary to convince the partners in the building process of the importance of good organization. A good organization will help to achieve: short design and construction periods, simple and manageable programmes, feasible quality of construction, minimum loss in time and cost when changes in the design or construction have to be made, good cooperation between the partners, safe and human working conditions.

2. PARTNERS IN THE BUILDING PROCESS

One of the most important question is:"How to improve cooperation between the different partners in the building process?" There are some specific groups of partners, the representatives of

- the owner or the client (government, cooperate, private)
- the consultants (architect, engineers)
- the contractor (one or more in joint ventures)
- the subcontractors (nominated or not nominated by owner)
- the suppliers (nominated or not nominated by owner)
- the people

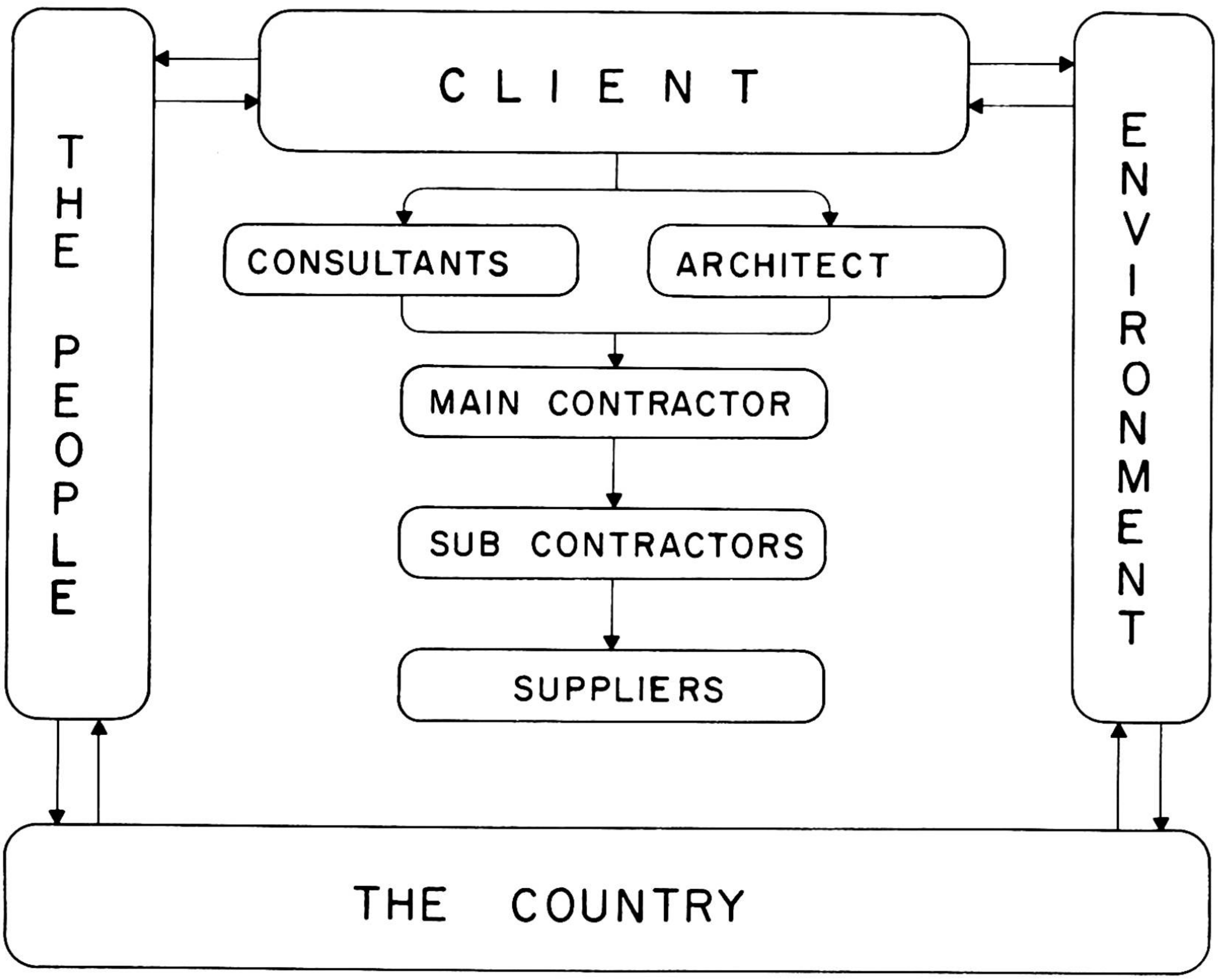


Figure 1: "Partners" in the building process

We have to consider the fact, that a project has to meet finally the objectives, the needs of "the people", the people who wish to have more influence on what will be built at which location, the people who have to live in or have to learn to live with these buildings, the people who have to pay directly or indirectly the cost of buildings etc. When organizing design and construction of a large project, one has to recognise and consider the different attitudes of the partners in the building process. In each case we have to decide, when and in what way each partner will be involved as we proceed with design and construction. In large project on a international level, we will find different points of view between continents and countries; the social structure of the country in which the project should be realized has to be respected.

A special problem arises, when the environment of bordering countries is influenced by large projects (e.g. nuclear power stations located close to the border, upstream industries which pollute a main river). The organization has to involve the necessary partners on the respective political level.

3. ENGAGING THE BUILDING PROCESS PARTNERS

How far should a design be prepared by the project organization, before new partners will be integrated in the building process? We know that the client chooses an architect or an engineer as a consultant early in the process. Only in the later phases the main contractor, the subcontractors and the suppliers are selected. The method and the point of time to enlist these partners will influence the organization and is of great importance for the programme in the following phases.

To have these partners activ in the building process as early as possible will prove time-saving and advantageous to improve cooperation in early stage. To apply similar selection criteria in the choice for partners in the field of execution as are applied to select consultants, would possibly bring better results, the decisive factor in construction is not only the lowest bid, but also reliability, know how, experience, cost-conscientiousness. Through an early contribution of the know how of these construction partners to the design of a building, it will be possible to come to the most satisfactory solution.

4. ORGANIZING THE BUILDING PROCESS

If the construction partners are choosen early in the design phase, the design of the building and the preparation of the execution can be carried out at the same time and the experiences of the contractors can be brought into the design. When we analize planning procedures applied in the building process, we realize that only those methods can effectively be used, which will be accepted by all partners. To keep track of the immense amount of informations and to operate a well adapted communication-system is the final objective in planning design and construction in large projects.

For large building projects we will introduce the following levels in the planning process:

- the overall plan (all partners together)
- the master plan (each partner on his own)
- the work programme (each partner on his own)
- the working schedule (each partner on his own)

5. THE OVERALL PLAN

To enable the project-team to take the right decisions at the right time, this team should have an overview of the whole project. The members of this team should know which partner has to do what kind of activity at which moment; and as a partner we define the representatives of the client, the architect, engineer and consultant, as well as the contractors and the suppliers. To develop an "overall plan", the project team has to know: the requirements, the technological dependences between main activities, the economical relations between these main activities, the budget.

It is essential that the project team achieves full agreement between all partners, the overall plan will then be used as a general guide line. All future decisions have to be deduced from this overall plan which contains a certain number of milestones, in which different activities of several partners meet and may influence eachother. When a deviation to the overall plan develops, the consequences can be made visible, the necessary corrections can be enforced. To make such an overall plan, it will be necessary to take the following steps:

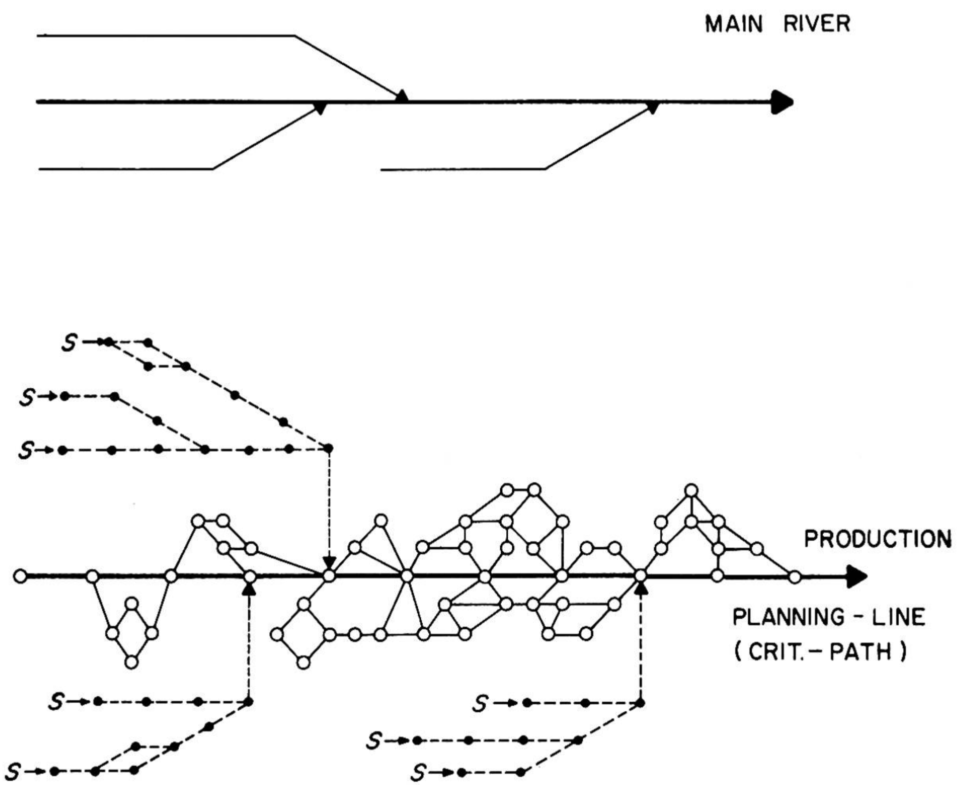
- analyse owner's requirements
- confer between partners
- make a first draft of the plan
- test this draft against the ideas of the different partners
- make the final draft of the plan
- settle the overall plan after consideration by all partners and have it signed.

6. THE MASTER PLAN

Each partner's activities have to be coordinated along the accepted overall plan. That means that each of the partners has to work out his own plan, in which all his activities will be integrated. We call this plan the master plan. Therefore, we have one overall plan and as many master plans as partners. Each master plan is made after analysing every subactivity to be executed, they have to meet the milestones of the overall plan. The master plans have some kind of flexibility, they are also interlocked into the overall plan.

7. THE WORK PLAN

The different subactivities within the master plan can be grouped into adequate workprogrammes which are actionorientated. In such workprogrammes we consider different standards, type of labour, equipment and material. We would like to know in what time, with how many men and with what kind of equipment and material we have to handle what type of work with what sort of technique. The workprogramme will be used for construction, but also in the design-phase for design-decisions, design-calculations, cost-calculations etc. Workprogrammes will not be flexible, they fix for the next period the necessary steps to be taken. The programme must be clear to all people who have to work with it.



S : STARTING POINTS FOR SEVERAL ACTIVITIES, PREPARATIONS, DECISIONS, TO MAKE THE ACTIVITY ON THE CONSTRUCTION SITE POSSIBLE.

Figure 3: Principle of "logic diagram"

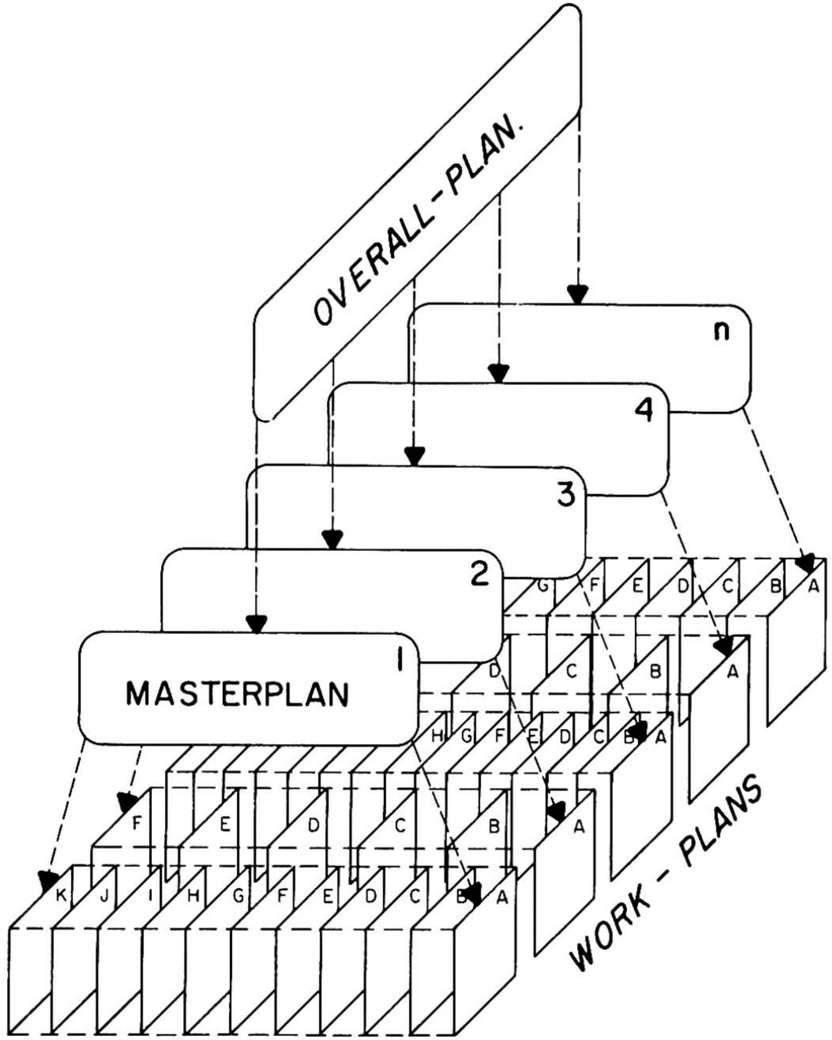


Figure 2: planning-levels

8. THE WORKING SCHEDULE

In the last level of planning we find the working schedules in which the instructions for the different tasks are given. Tasks must be performed within fixed periods and the instructions must therefore be clear to men working on site, at drawing-boards etc.

9. THE LOGIC-DIAGRAM

It becomes more and more important to plan not only the sequence of the activities of the building process, but the preparatory actions for each activity, or at least for the main activities, as well. This means that parallel to the real workprogramme activities, preparatory activities must also be analysed. When we compare the workprogramme with a river, in which the critical path is considered as the main stream, we can imagine that this main stream must be fed at vital places by a lot of secondary rivers. The rivers stand for activities to be completed before the main activity in the work plan can be started. Questions like these will help to define preparatory activities: What kind of things must be present? What materials must have been supplied? What kind of drawings do we need? What equipment is necessary to execute this activity and how do we get this equipment to the building site?

These preparatory activities can be analysed and shown in the "logic-diagram". The logic-diagram helps to identify the most important tasks in the buildings-process.

10. CONCLUSION

Organizing design and construction of large projects is a complex task. Time, cost and quality of the realized building depend directly on the quality of the organization, the selected partners form the organization. Good cooperation and communication are decive aspects of the organization, the early selection of the construction partners helps to coordinate design with the preparation of the execution.

IIIb

Construction Management

Gestion de projet

Baumanagement

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SUMMARY
Construction Management at the Owner's level does ask for three well functioning main systems: an Estimating and Budgeting System, a Planning and Scheduling System and a Cost Control System. Regardless of whether the Owner performs part of the functions by his internal Organization or the CM Consultant performs all of the functions, it is sophistication in these management tools that will determine whether Construction Management is able to project a realistic budget in cost and time to impose the necessary control.

RESUME
La gestion de projet au niveau du maître de l'ouvrage requiert trois outils de gestion bien rôdés: un système de budget et d'estimation de coûts, un système de planification et de délais, et un système de contrôle des coûts. Le maître de l'ouvrage peut exécuter une partie de ces fonctions de gestion de projet, à l'aide de sa propre organisation ou peut confier ces tâches à un ingénieur-conseil en gestion de projet. Mais en définitive, le succès du programme en coûts et en temps dépendra des contrôles nécessaires imposés par les outils de gestion.

ZUSAMMENFASSUNG
Das Baumanagement auf der Stufe des Bauherrn baut im wesentlichen auf drei gut aufeinander abgestimmte Führungshilfsmittel auf: ein Ablaufplanungssystem, ein Kostenbudgetierungssystem und ein Kostenkontrollsystem. Unabhängig davon, ob der Bauherr mit seiner Bauherrenorganisation einen Teil der Baumanagementfunktionen selber übernimmt oder ob der Baumanagementberater des Bauherrn alle Funktionen übernehmen muss, geht es letztlich um den zielgerichteten und zweckmässigen Einsatz der Führungshilfsmittel, wenn man mit Erfolg ein realistisches Budget der Kosten und der Bauzeit erarbeiten und die notwendige Kontrolle durchsetzen will.

THE OWNER'S PROBLEM

Buildings of today are complex and costly. The Owner is seldom the end-user of the building he proposes to build. He regards the building as an investment and wants a maximum return on every dollar invested.

Once a project is conceived and its feasibility determined, he is under unparalled pressure to complete the project on time and within budget to get this return on his investment.

In today's market, a project is conceived, designed, financed, built and leased by independent groups of developers, architect-engineers, bankers, general contractors, sub-contractors, vendors, leasing and management agents. Each group must perform hundreds of activities under conditions and restraints that are beyond each particular group's control. Change in the availability of financing, or lack of a trade's progress due to changes in the labor market, or uncontrolled design changes during construction, or delays in deliveries can affect the project's timetable without warning and jeopardize the Owner's return on his investment.

The major cost of the project is generally determined by the design concept developed in the early stages of the design process. In this initial period, the architect, the Owner, and their consultants rapidly arrive at a preliminary design. Once work commences on that design, it becomes more and more difficult to make changes in the original concept. Designs and costs are locked in.

The Owner, in making decisions during the design process, basically relies on his AE's cost projection and knowledge of construction methods. The Owner has no reliable basis for judging the design for its practicality regarding construction process, or for choosing an alternate process that could produce a cost savings without a decrease in functional quality. Because of this, alternate solutions are known only after the bids are in. If the bids are high and over budget, lengthy negotiations on design changes must be made. At that point, changes that could easily have been made during the early stages, become costly and time-consuming.

CONSTRUCTION MANAGEMENT FUNCTIONS AND THEIR ROLE IN DECISION MAKING

There are a variety of management decisions that must be made during stages of the conceptual design, the design, the construction and the beneficial occupancy. At every decision point, the Owner's primary concern is whether his decision will meet his basic objectives of completing the project on time and within budget.

The establishment of budget costs (trade costs) and budget time (completion time) are the two most important functions during the design stage which provide a framework for control during construction.

The total cost of the project is minimized, not merely by minimizing time of design or construction but through numerous interactions between design, material alternates, competitive bidding processes, contract negotiations, and effective coordination of design and construction activities.

Let us assume that the Owner has accepted the architect's original design of an office building with aluminium curtain wall. After the bids for curtain wall were in, it was found that the lowest quote was $ 100,000 above the Owner's budget. Upon further investigation, it was realized that an alternate design with precast concrete curtain wall could be installed at $ 100,000 less than the budget. However, the installation of the concrete curtain wall will take four weeks longer than the aluminium curtain wall. Now, what should the decision be?

The apparent answer is to choose concrete curtain wall. But is it? A pragmatic decision will require an analysis of the impact of delays over: 1) completion of the project and related cost increases, if any; and 2) the delay in the beneficial occupancy and related loss of revenues. A further sophistication may require a risk analysis for both systems before the Owner can effectively choose one system over the other.

Let us assume another situation for a high-rise apartment building. During the design stage, the architect-engineer determined that the "through-the-wall units" heating and cooling system will be $ 250,000 cheaper than the central heating and cooling system. However, the operating costs including energy costs are expected to be $ 25,000/year less for the central system. Now, which system should be selected?

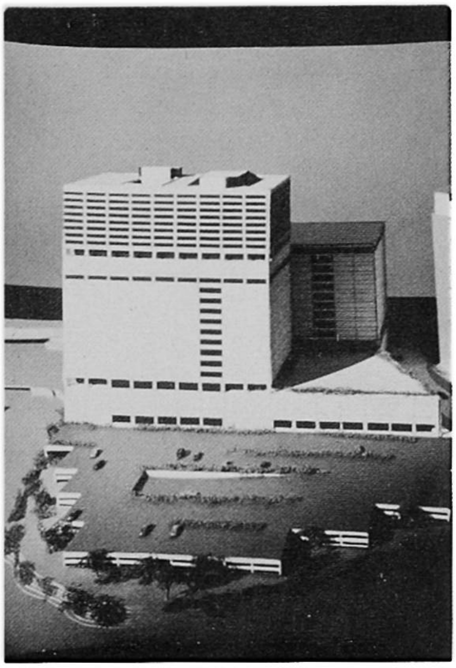
The answer is not simple. To make a decision, we must determine the life-cycle cost for both systems. We must have the data on operating costs including maintenance and replacement of parts of equipment during the same life-cycle. In addition, we must analyze the interrelated cost of other trades. For example the cost of window wall system and electrical work will be different in "through-the-wall units" than in the central system.

To meet the Owner's need of making business decisions that are timely and effective, one must have access to systems which can be used as a tool to analyze and synthesize information for decision making purposes.

Basically, the Owner-CM will need three main systems: 1) Estimating and Budgeting System, 2) Planning and Scheduling System, and 3) Cost Control System. Regardless of whether the Owner performs part of the functions internally or the CM performs the entire functions for the Owner, it is sophistication in these management tools that will determine whether CM is able to project a realistic budget or monitor a cost trend and schedule slippage that will seriously affect the Owner's budget and jeopardize his competitive advantage in the market. For example, without the capability of sophisticated planning and scheduling tools, one would not be able to properly compress the schedule by phasing design and construction, thereby saving construction costs for both materials and labor in an inflationary market, and insuring a smooth running project through effective dovetailing of different operations and trades. Similarly, without a good change-order-work control relating to scope and budget, the cost control system will lose its significance.

The following pictures provide some of the projects completed on a Construction Management basis:

SUMMIT TOWERS: The complex consists of three 44-story apartment buildings connected by a 12-story base structure for parking, a theatre, commercial space and recreation facilities.



APPAREL MART AND HOTEL: This composite steel and concrete structure comprises a hotel and an apparel mart with 125,000 square meters of space.

DETROIT RENAISSANCE: This is a very large and complex project consisting of a 70-story concrete structure hotel, four 39-story steel structure office buildings connected with a 7-story concrete podium for parking and commercial space.

IIIc

Design Management for Hong Kong Metro

Direction de projet pour le métro de Hong Kong

Entwurfsleitung für die Hong Kong Metro

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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

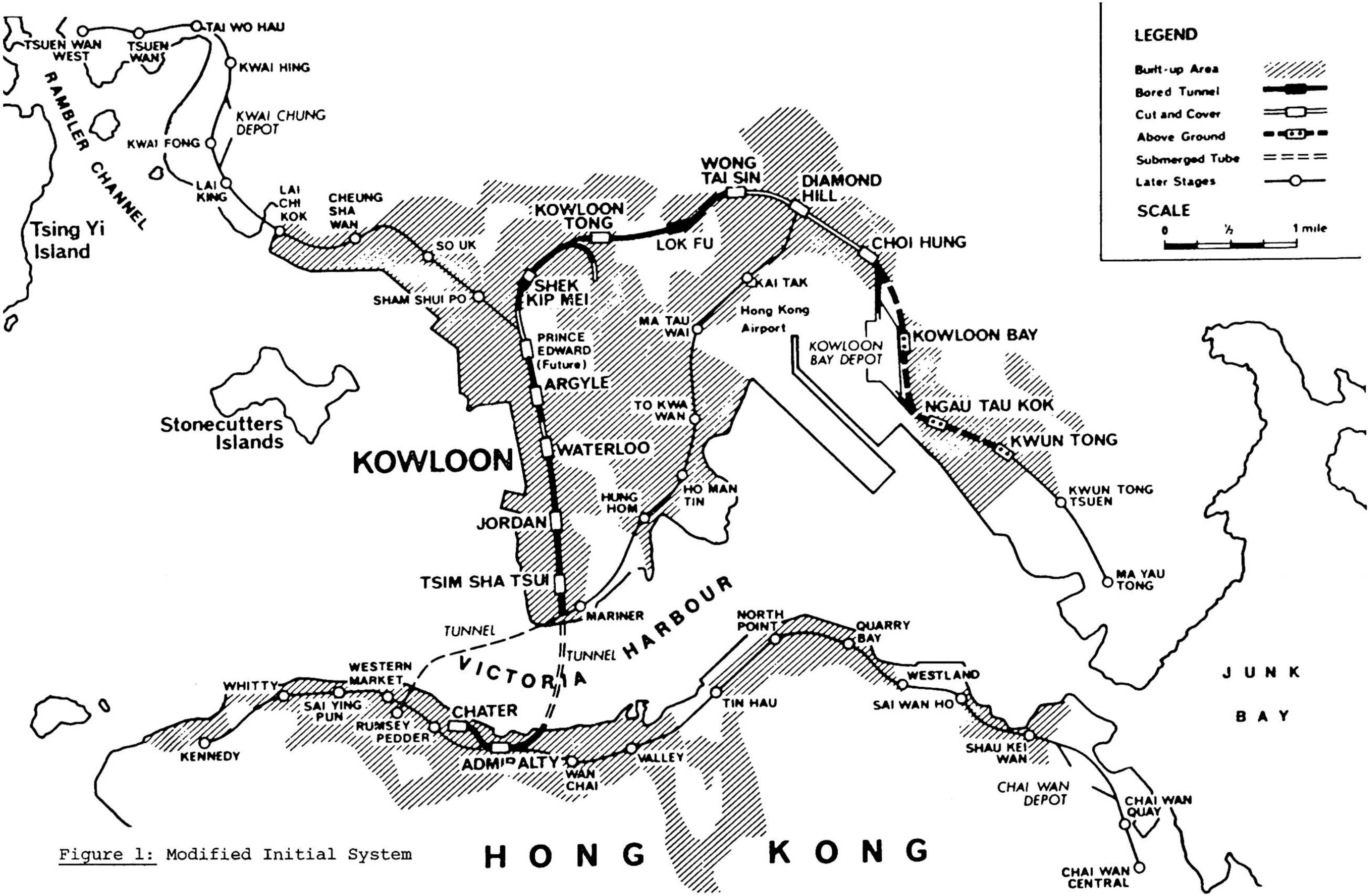

Figure 1: Modified Initial System

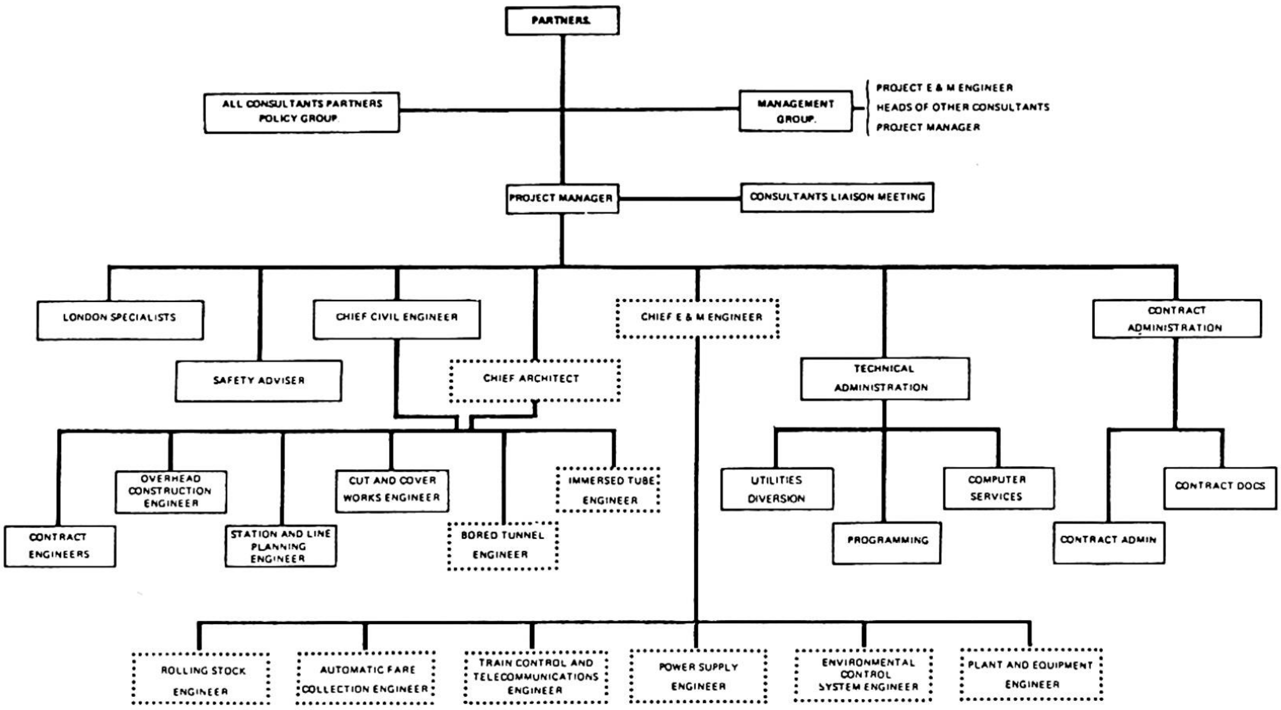

Figure 2: Consulting Engineer's Organisation

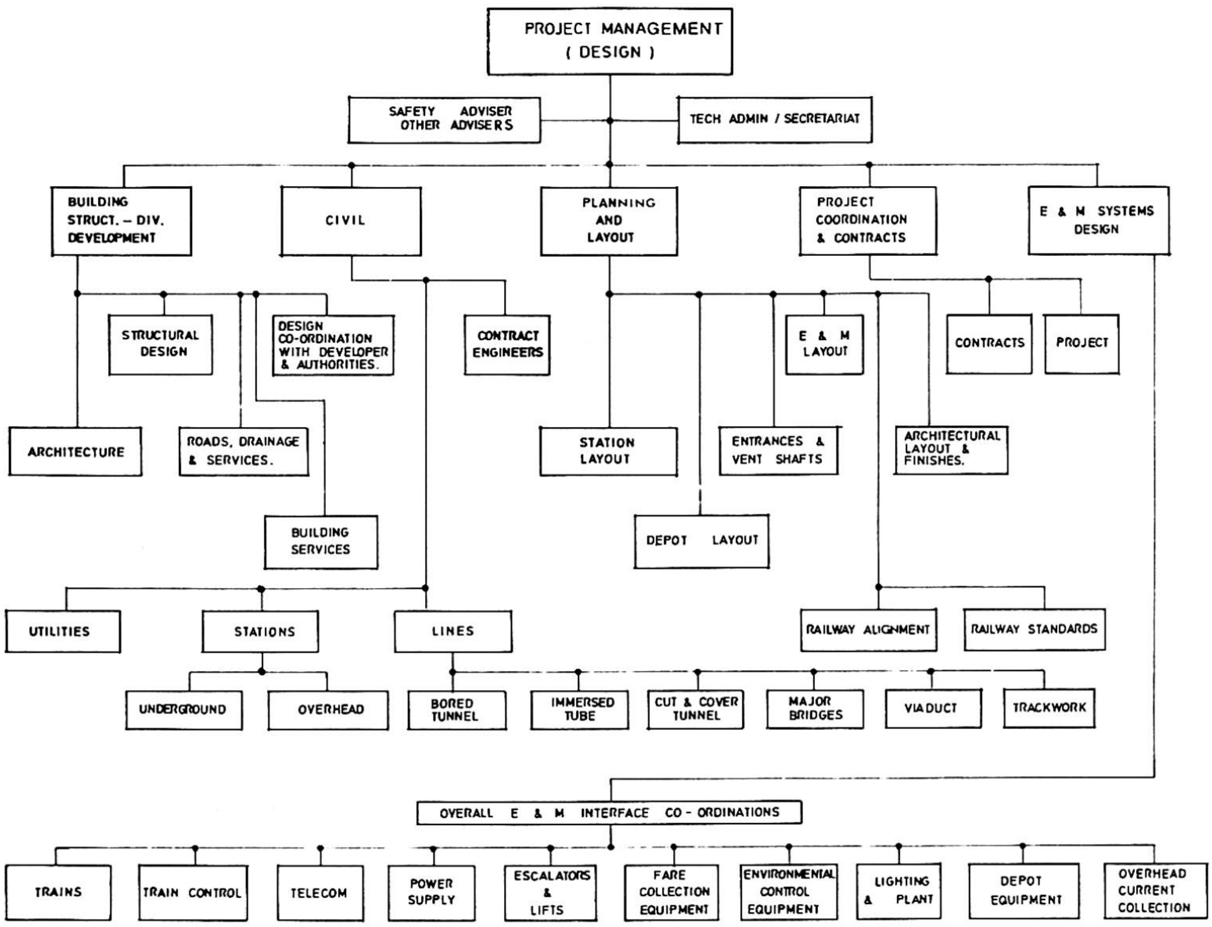

Figure 3: Project Management

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

SUBJECT \ BODY	CLIENT	CONSULTING ENGINEER	SAFETY CONSULTANT	CONTRACTOR	GOVERNMENT SECRETARIAT	BUILDING ORD. DEPT.	HIGHWAY DEPT.	DRAINAGE DEPT.	WATER DEPT.	TRAFFIC DEPT.	POLICE	FIRE BRIGADE	ELECTRICITY CO.	LIGHT & POWER CO.	TEL CO.	CABLE & WIRELESS	GAS CO.	REDIFFUSION	ARRA…
MANAGEMENT	●	●		●															
COMMERCIAL	●	●		●															
FINANCE	●	●		●															
ESTATES	●	●		●	●														
OPERATIONS	●	●		●	●						●	●	●	●					
LAND ACQUISITION	●	●			●														
WAYLEAVES	●	●			●														
LINE PLANNING	●	●			●		●	●	●	●	●	●	●	●	●	●	●	●	●
STATION PLANNING	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
ARCHITECTURE	●	●	●		●	●													
UNDERGROUND STATION DESIGN	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
OVERHEAD STATION DESIGN	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
UNDERGROUND STRUCTURES	●	●		●	●	●													
OVERHEAD STRUCTURES	●	●		●	●	●													
IMMERSED TUBE TUNNEL	●	●	●	●															
BORED TUNNEL	●	●	●	●															
TRAINS	●	●	●	●	●						●	●							
TRAIN CONTROL (SIGNALLING)	●	●	●	●	●								●	●					
TELECOMMUNICATIONS	●	●	●	●	●								●	●	●	●			
POWER SUPPLY	●	●	●	●	●							●	●	●					
STATION LIGHTING	●	●	●	●	●						●	●	●	●					
ESCALATORS	●	●	●	●	●						●	●							
FARE COLLECTION	●	●	●	●	●						●	●							
VENTILATION	●	●	●	●	●	●					●	●							
PUMPS	●	●	●	●	●		●												

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.

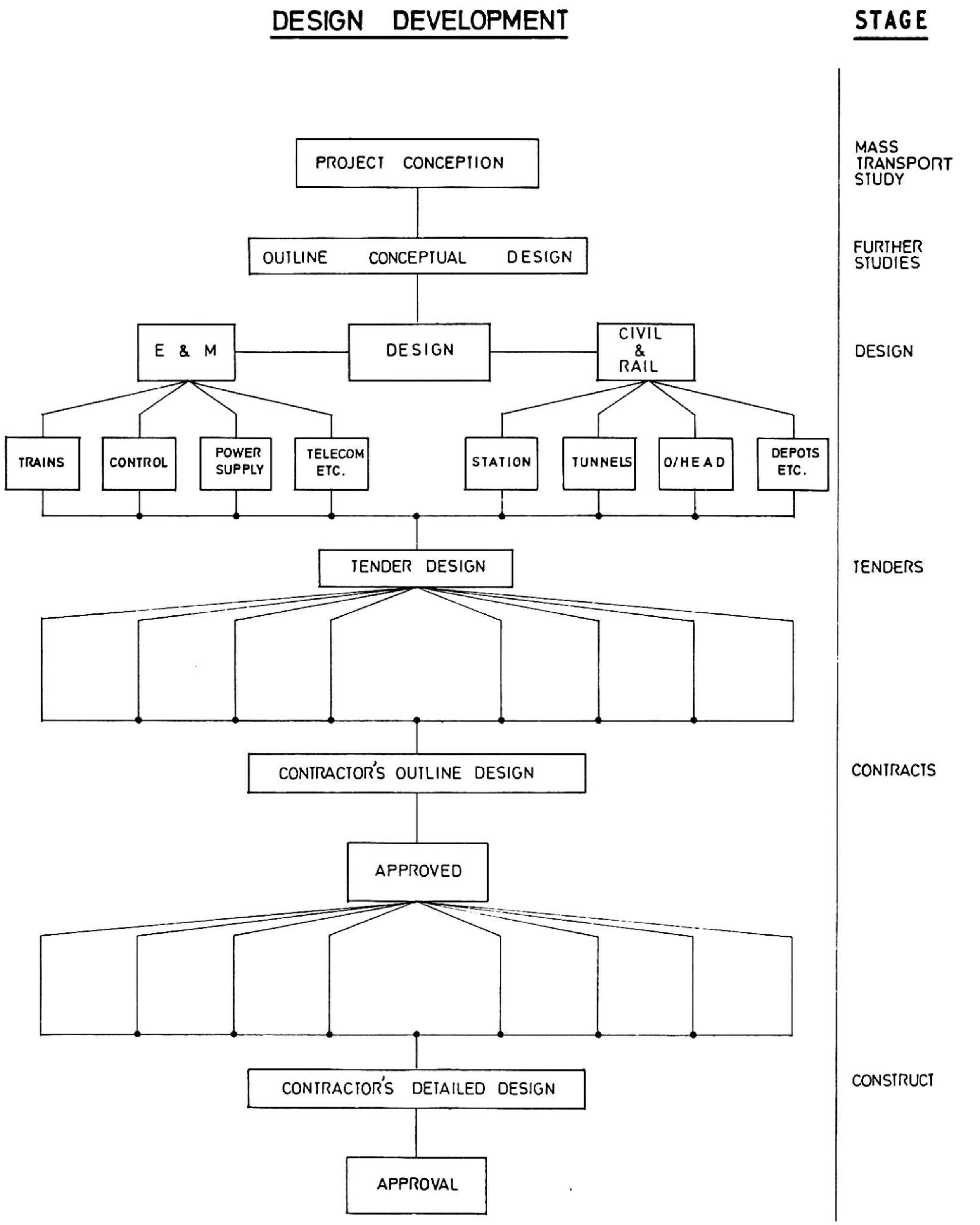

Figure 5: Design Development

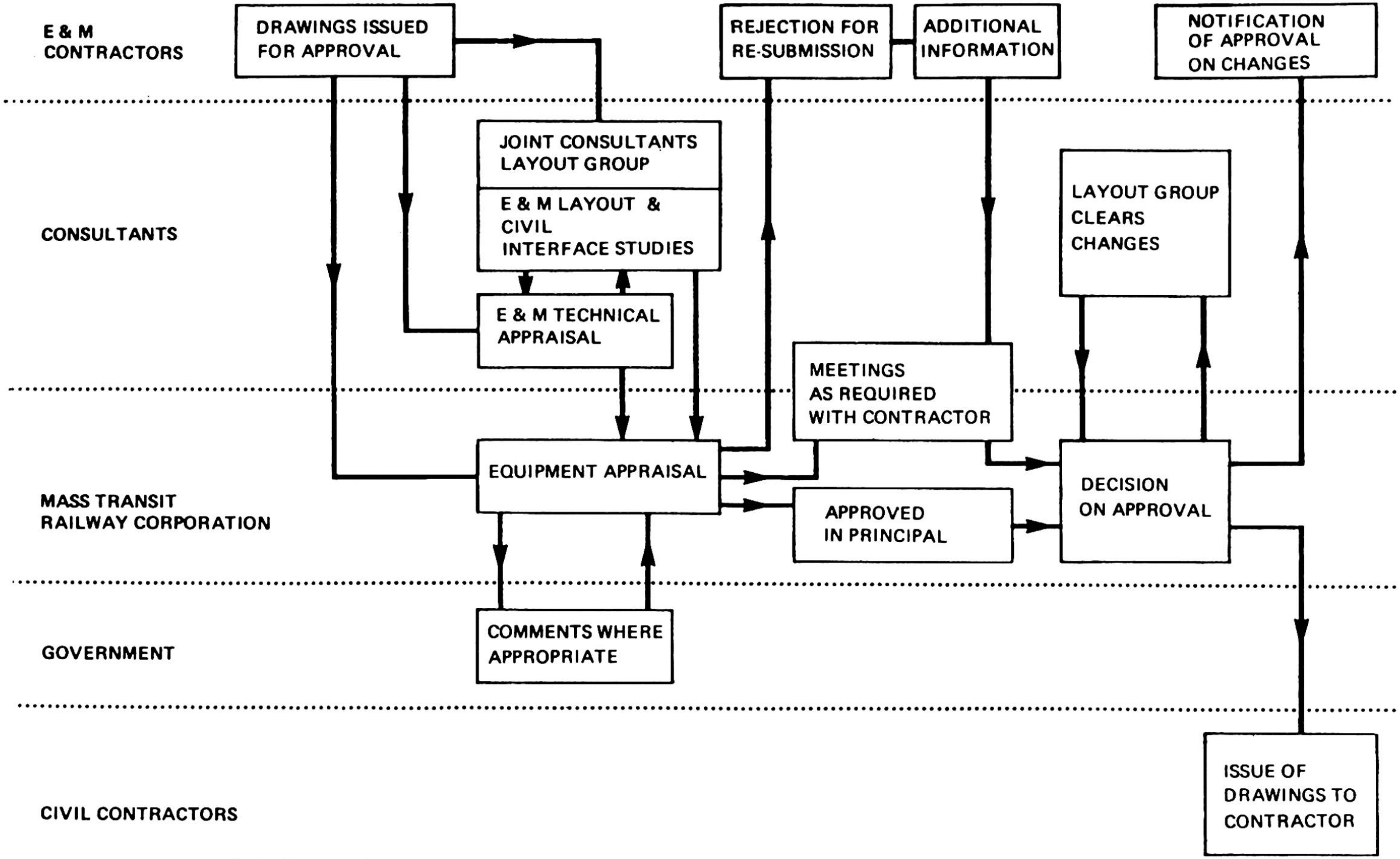

Figure 6: E & M/Civil Drawings

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.

APPROVAL OF CONTRACTOR'S WORKING DRAWINGS

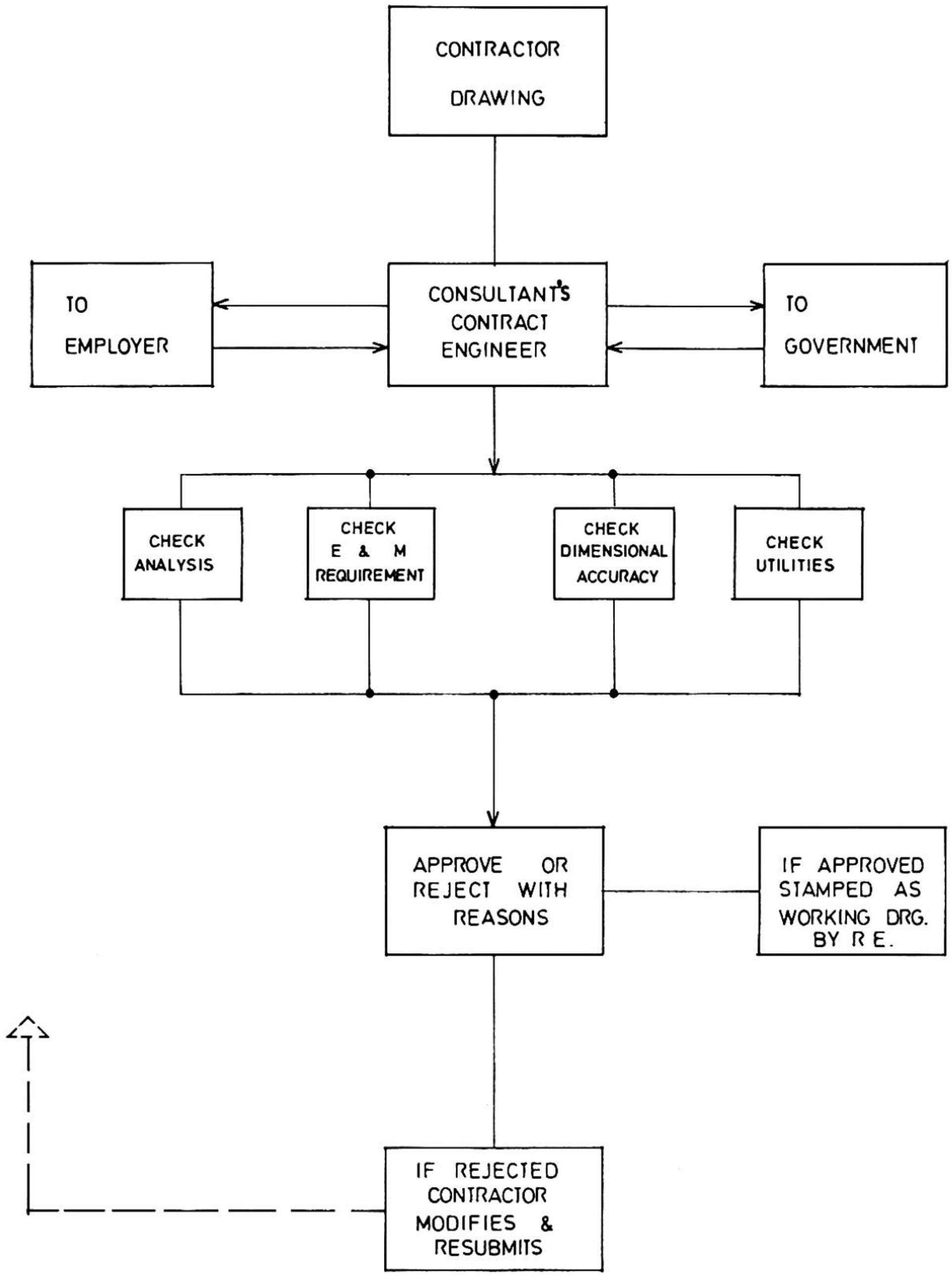

Figure 7: Approval of Contractor's Working Drawings

IIId

Management-Entscheidungen im Baubetrieb am Beispiel der Untergrundbahn München

The General Contractors' Management Problem in the case of a Munich Metro Contract

Problèmes de gestion de la construction, dans le cas du métro de Munich

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ZUSAMMENFASSUNG
Grosse und komplexe Bauaufgaben, deren Planung und Ausführung sich über weite Zeiträume erstrecken, bieten den ausführenden Unternehmungen besondere Gelegenheit, um eigentliche Angebotsstrategien zu konzipieren und in konstruktiver wie verfahrenstechnischer Hinsicht echte Ausführungsvarianten zu erarbeiten. Dabei spielen die Einflussfaktoren Umwelt, Marktsituation, Bauverfahrensmöglichkeiten in den wichtigen Entscheidungsbereichen eine dominante Rolle. Am Beispiel des Loses 9 der Untergrundbahn München werden die entscheidenden Managementprobleme dargestellt.

SUMMARY
In long range projects contractors have a unique opportunity to develop bidding strategies and special construction techniques. Environment, market and technological alternatives play a dominant role in the important management decisions. Construction is now carried out for the contract 9 of the Munich Metro. In this case study the main decisions for this contract are presented.

RESUME
Les mandats importants et complexes, dont la planification et l'exécution s'étendent sur une longue durée, offrent aux entreprises la possibilité unique de concevoir de propres stratégies de soumission et de réelles alternatives d'exécution. Des facteurs tels que l'environnement, la situation du marché, les méthodes de construction applicables jouent un rôle déterminant dans les décisions. Les problèmes de gestion de la construction sont présentés dans le cas du lot no 9 du métro de Munich.

1. EINFUEHRUNG

In München ergibt sich durch die zentrale Lage im süddeutschen Raum eine starke Konzentration der deutschen Bauindustrie. Dies führt zwangsläufig zu einem harten Wettbewerb. Die Bauprojekte des U-Bahn-Referates der Landeshauptstadt München sind aus verschiedenen Gründen für alle Konkurrenten besonders interessant:

- Das Bauvolumen des U-Bahn-Referates mit einem Rohbauanteil von 180 - 200 Mio DM im Jahr liefert einen grossen Anteil am gesamten Tiefbauauftragsbestand.

- Das einmalige Finanzierungsmodell dieses Referates ermöglicht es, dass dieser Jahresetat auf viele Jahre vorprogrammierbar ist.

- U-Bahn-Bauten im städtischen Bebauungsgebiet erfordern von den Bietern eine beachtliche technische Kapazität.

Der gewaltige Umfang des Projektes, die Möglichkeit langfristiger Planung und die technische Herausforderung dieser Bauvorhaben sorgen somit dafür, dass dieser Marktanteil besonders hart umkämpft ist. Das dadurch hervorgerufene Prestigedenken lässt die Preise in manchen Zeitphasen sogar unter die Herstellkosten absinken.

Die Unternehmer versuchen deshalb immer wieder, durch technische Innovationen dem Markt neue Impulse zu geben, um die eigenen Chancen im Wettbewerb zu verbessern. Eine solche Neuerung stellte z.B. die Einführung und Entwicklung des einschaligen Tübbingausbaues beim mechanischen Tunnelvortrieb dar. Die Entwicklung einer Variante der NATM (Neue Austria Tunnel Methode) soll hier als Beispiel für Management-Entscheidungen im Baubetrieb gewählt werden.

2. PROJEKTWAHL UND ENTSCHEIDUNGSVORGAENGE

Ein wesentlicher Anteil der U-Bahn-Bauten muss in dicht besiedelten Gebieten erstellt werden. Nicht immer ist es möglich, die U-Bahn-Linie unter breite Strassen zu legen, vielmehr müssen sinnvoll geführte Linienzüge oft Gebäude und Bebauung unterfahren. Dies führt zwangsläufig zur Anwendung bergmännischer Bauweisen. Im Jahr 1974 waren dies konventionelle Vortriebsmethoden und mechanische Schildvortriebe. Der Markt schien in bezug auf die Technologie zu stagnieren. Die Wettbewerbssituation war aus diesem Grund ausserordentlich verhärtet. Die Ausschreibung des umfangreichen Bauvorhabens U-Bahn-Bahnhof Sendlinger-Tor-Platz und Strecke bis zum Hauptbahnhof wurde deshalb zum Anlass genommen, die Anwendbarkeit neuer Technologien zu überprüfen.

Die äusseren Bedingungen für die Wahl der anzuwendenden Bauverfahren waren durch zwei besondere Probleme gegeben:

- Die geologischen und hydrologischen Bedingungen des Untergrundes in München.
- Die Notwendigkeit, im Bereich des Sendlinger-Tor-Platzes grossflächige Querschnitte (über 100 m^2) aufzufahren, dabei einen bestehenden Bahnhof zu unterfahren und später im Bereich des Hauptbahnhofes mehrgleisige Verzweigungsharfen herzustellen.

Erfahrungen mit der Anwendung der NATM im U-Bahn-Bau lagen aus der Stadt Frankfurt vor. Die geologischen Verhältnisse unterscheiden sich dort allerdings wesentlich von denen in München. Die Querschnitte beschränkten sich ausserdem auf eingleisige U-Bahn-Strecken.

Bild 1: Streckenführung der U-Bahn in Müchen

Die Ausarbeitung einer Variante dieser Technologie zur Bewältigung der gestellten Aufgaben erschien nur dann sinnvoll, wenn sich aufgrund der Ueberprüfung der Marktsituation abzeichnen sollte, dass diese Neuentwicklung - über das Los Sendlinger / Tor-Platz / Hauptbahnhof hinaus - auch auf andere Bereiche des U-Bahn-Baues anwendbar wäre. Mit anderen Worten, es ergab sich die Forderung, aus dieser Variante ein allgemein anwendbares Verfahren zu entwickeln.

Aufgrund der Auswertung einer Matrix über die Marktsituation (Bild 2) und der daraus abzuleitenden Annahme, dass für ein solches Projekt aussichtsreiche Voraussetzungen vorhanden waren, wurde beschlossen, die Möglichkeiten der NATM zur Lösung der anstehenden Probleme zu nutzen.

Diese Entscheidung wurde aufgrund einer adaptiven Strategie, die die einzig erfolgversprechende Unternehmenshaltung in diesem Marktsektor zu sein schien, getroffen.

Um innerhalb der zur Verfügung stehenden Bearbeitungszeit zu einer klaren Disposition zu kommen, wurden für die Erstellung eines chancenreichen Angebotes verschiedene Entscheidungssituationen definiert, die die Grundlage für weitere Bearbeitungsschritte bilden sollten.

Marktsituation:
Da die Auswertung der Marktsituation zu einer positiven Entscheidung führte, wurden die technologischen Probleme in Angriff genommen.

EINFLUSSFAKTOREN / BAUVERFAHREN	ÄUSSERE EINFLÜSSE				INNERE EINFLÜSSE			
	UMWELT ALLGEMEINE BEEINTRÄCHT.	UMWELT VERKEHRS-BEEINTRÄCHT.	MARKT-SITUATION	WETTBEWERBS SITUATION	TECHNOLOGIE	RISIKO	RESSOURCEN	INVESTITIONEN
OFFENE BAUWEISE	STARK	STARK	–	–	BEKANNT	–	VIEL FACH-ARBEITER	–
BERGMÄNNISCH KONVENTIONELLE ODER MECHANISCHE BAUWEISE	GERING	GERING	0	$\overline{0}$	BEKANNT	0	0	+
BERGMÄNNISCH NATM (NEUE ÖSTERREICH. TUNNELBAU-METHODE)	GERING	GERING	+	+	Z.T. UNBEKANNT	+	–	–

Bild 2: Entscheidungs-Matrix für Bauverfahren im U-Bahnbau

Bild 3: Adaptive Strategie als Grundlage für eine Management-Entscheidung

Konstruktive Bearbeitung:
Die konstruktiven Probleme wurden von Pacher - Laabmayr in Salzburg bearbeitet. Die Bearbeitung der verfahrenstechnischen Probleme wurde im Rahmen der Bietergemeinschaft durchgeführt. Es musste in einigen Details mit Annahmen operiert werden, die statistisch nicht belegbar waren und daher keinerlei Hochrechnung bezüglich der Wahrscheinlichkeit ihres tatsächlichen Eintretens zuliessen.

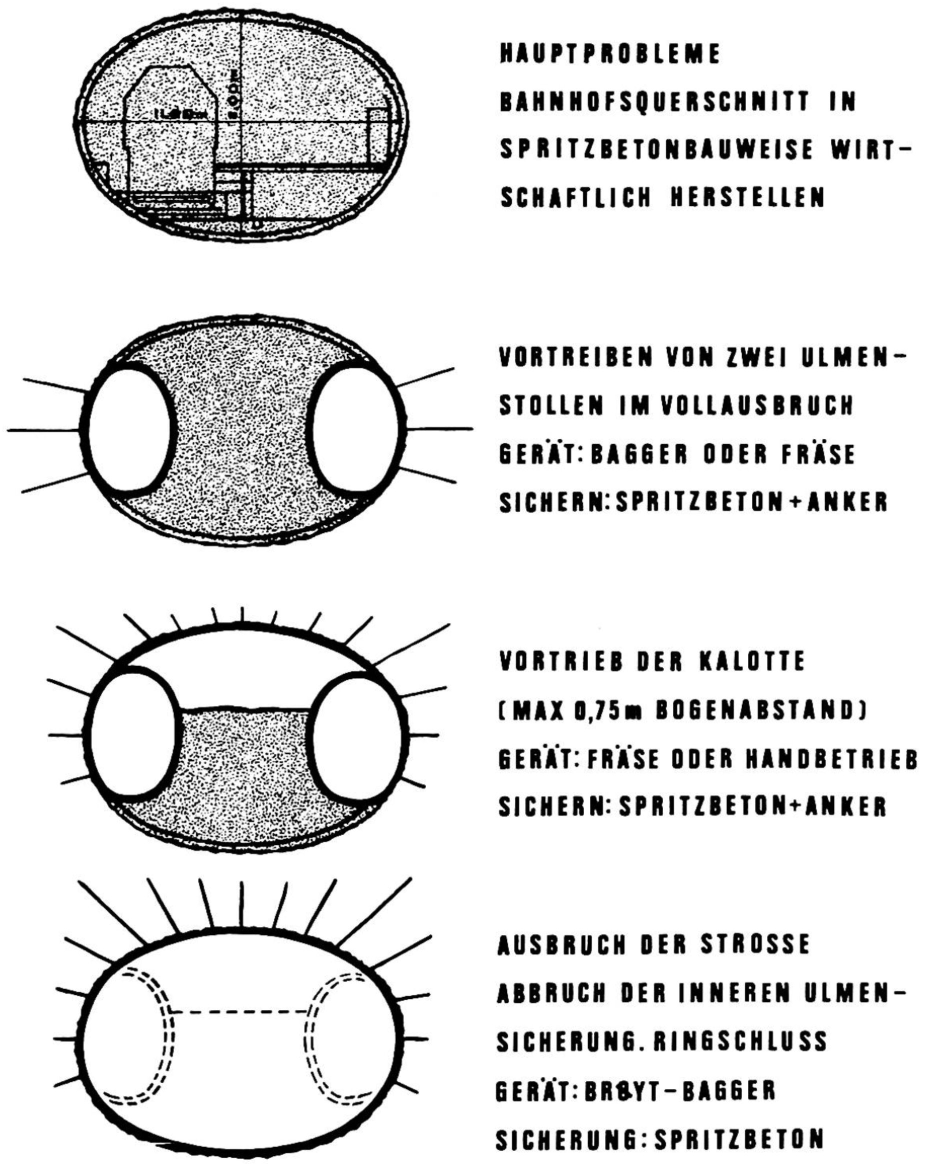

Bild 4: Konstruktion und Ausführung

Preis:
Nachdem sich aber gezeigt hatte, dass die NATM sowohl hinsichtlich der Konstruktion als auch in der Ausführung Lösungen ermöglichte, wurde auch die Preissituation durch Ausarbeitung eines Leistungsverzeichnisses untersucht. Hier ergab sich erfreulicherweise eine eindeutige Entscheidung zugunsten des neuen Verfahrens, obwohl auch in diesem Bereich einige Kostenbestandteile sehr schwierig zu kalkulieren waren.

Insbesondere die Annahme einer realisierbaren Leistung beim Vortrieb im Flinzsand im Bereich der Restwasserstände erschien ausserordentlich problematisch und erhöhte das finanzielle Risiko wesentlich.

Da alle Ueberlegungen und Untersuchungen trotz gewisser Imponderabilien zu einem insgesamt positiven Ergebnis führten, wurden die übrigen Schritte zur Ausarbeitung eines Angebotes in die Wege geleitet.

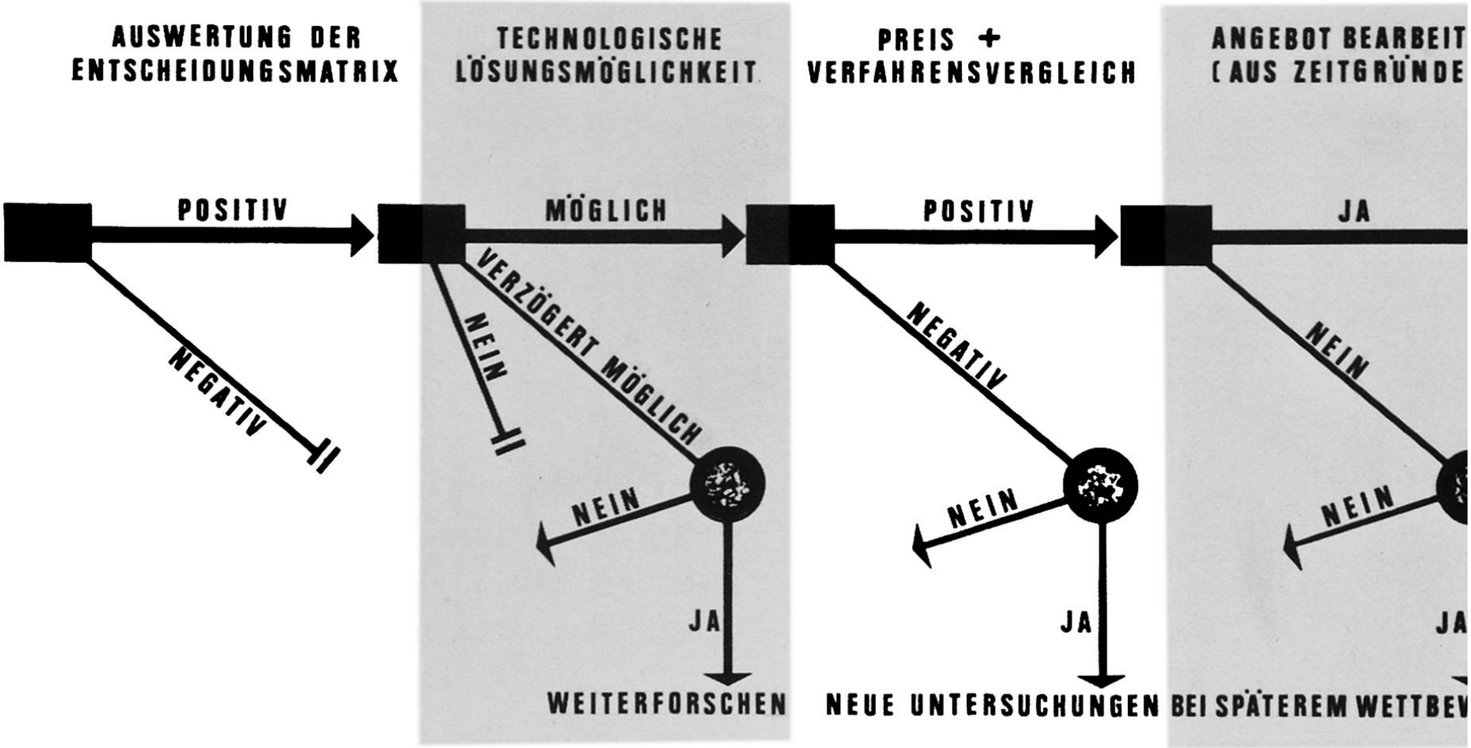

Bild 5: Entscheidungssituationen für die Angebots-Bearbeitung

3. ENTSCHEIDUNGSVORGAENGE FUER DIE VERTRAGLICHE ABWICKLUNG

Das Angebot lag - wie aus der Submission zu erkennen war - preislich in einem Rahmen, der den Bauherrn veranlasste, Verhandlungen über den Abschluss eines Bauvertrages aufzunehmen. Diese Verhandlungen sollten eine faire Grundlage für einen Bauvertrag, der die Rahmenbedingungen der VOB nicht verletzt, und die Anwendung einer neuen Methode berücksichtigt, liefern.

Es ergaben sich folgende Entscheidungssituationen:

Entscheidungssituation 1: Liegt der Sondervorschlag preislich günstig im Wettbewerb?

Entscheidungssituation 2: Kann eine Versuchsstrecke mit der neuen Methode vereinbart werden? Da sowohl dem Bauherrn als auch dem Unternehmer eine solche Lösung zur Ueberprüfung der Technologie sinnvoll erschien, wurde diese Frage mit "ja" entschieden.

Entscheidungssituation 3: Wie sind bei einem Versagen der neuen Technologie in der Versuchsstrecke die Bauarbeiten weiterzuführen?

Hier wirkte sich positiv aus, dass aus angebotstaktischen Ueberlegungen das Angebot der Bietergruppe für den Amtsvorschlag ebenfalls das günstigste war. Als Lösung konnte vereinbart werden, dass im Falle eines Misserfolges in der Versuchsstrecke die Arbeiten nach dem Amtsvorschlag auszuführen seien. Dies war eine Lösung, die zwar allen Forderungen der VOB gerecht wurde, das finanzielle Risiko des Unternehmers jedoch erhöhte.

Entscheidungssituation 4: Wie sieht die finanzielle Abwicklung der Durchführung dieses Bauvorhabens aus?

In Anlehnung an die Broschüre von Hochmuth zur "Praxis der Risikoverteilung bei Tunnelarbeiten unter schwierigen Bedingungen" wurden entsprechend Pauschalsummen, Limitsummen und Abrechnungen nach Einheitspreisen und Massen definiert.

Damit war eine vernünftige vertragliche Grundlage für die Abwicklung des Auftrages erarbeitet worden.

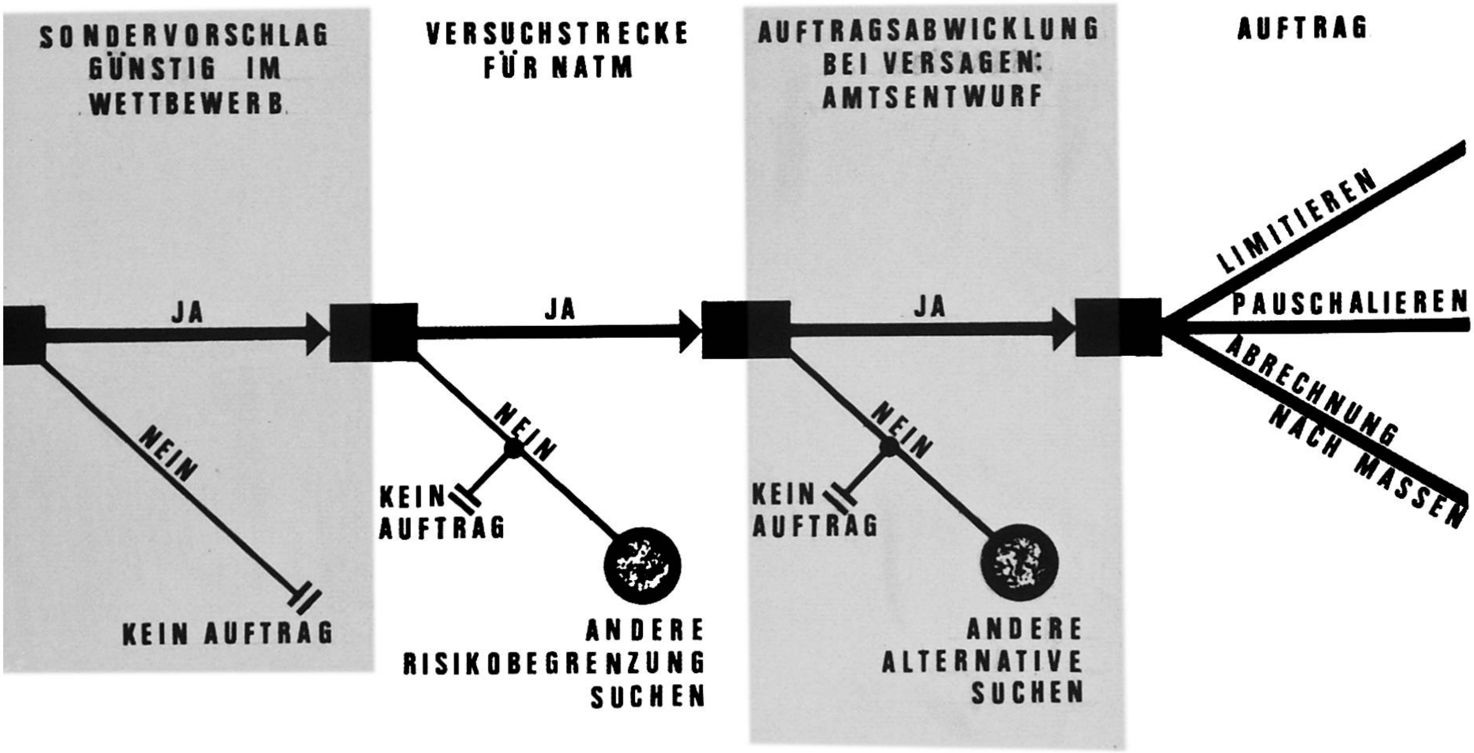

Bild 6: Entscheidungssituationen für die Auftragsverhandlung

4. OPTIMIERUNG DER BAUAUSFUEHRUNG

Da es sich im wesentlichen um neue Verfahren für die Bauausführung handelte, musste ein besonders sorgfältig gestaltetes Programm für den Einsatz der Mittel als auch für den zeitlichen Ablauf der Arbeiten ermittelt werden, wobei die wichtigsten Termine vom Bauherrn im Rahmen der Gesamttermine der U-Bahn vorgegeben wurden.

Für den Geräteeinsatz mussten verschiedene Einsatz-Varianten vorgesehen werden, da die Bearbeitung der geologischen Formation in Verbindung mit wechselnden hydrologischen Zuständen eine grosse Flexibilität erfordert, d.h. die eventuell notwendige Erprobung von Geräte-Varianten war besonders ausgeprägt zu berücksichtigen.

Dies und die Erwartung, dass Störungen im Bauablauf auftreten würden, führte zu einem Ablaufkonzept mit Ersatzquerschnitten im Vortrieb. (Ausweichquerschnitte zur Vermeidung von Wartezeiten).

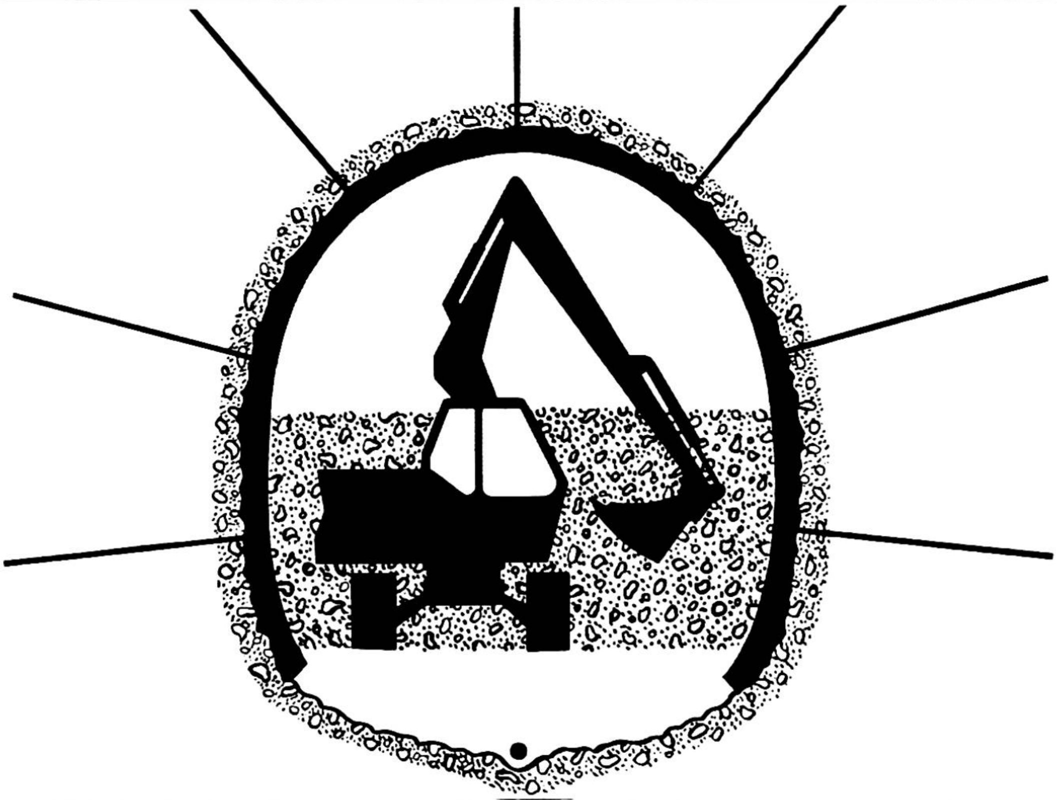

Bild 7: Gerätedisposition für einen eingleisigen Querschnitt

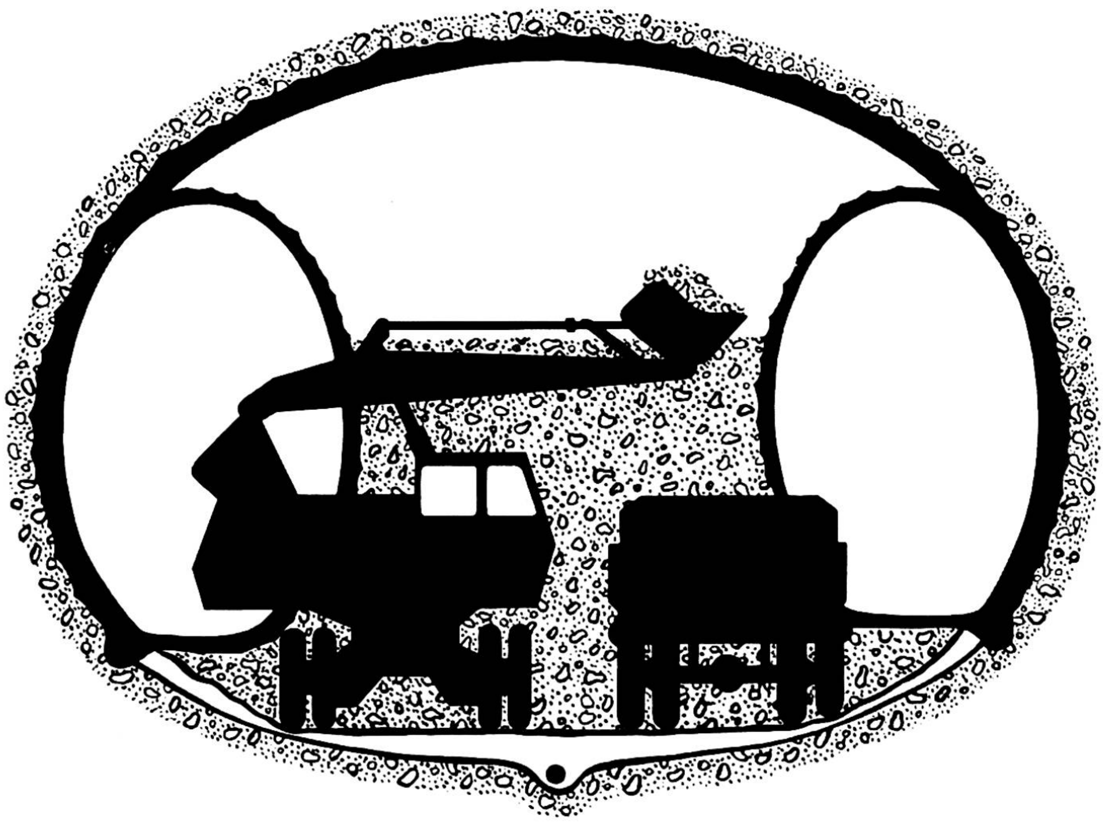

Bild 8: Gerätedisposition für einen mehrgleisigen Querschnitt

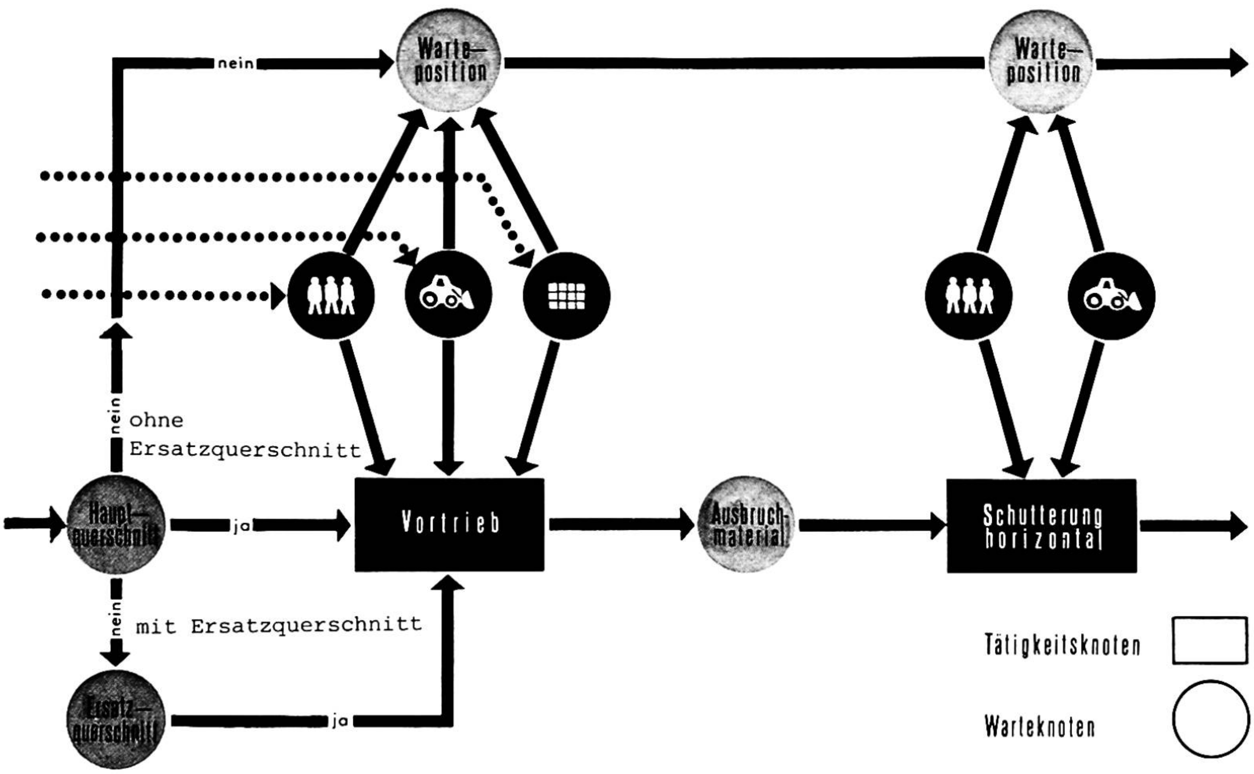

Bild 9: Das Prinzip des Ersatzquerschnittes

Die sich aus diesem Konzept ergebenden Varianten im zeitlichen Verlauf konnten mit Hilfe von Netzplantechnik und VZ-Diagramm (Volumen-Zeit bzw. Raum-Zeit) auch in anspruchsvollen Ablaufsituationen, wie z.B. bei der Verzweigungsharfe mit grossen Vortriebsquerschnitten, befriedigend gelöst werden. Die Gesamtarbeiten konnten sowohl im terminlichen als auch im wirtschaftlichen Rahmen des Angebotes ohne besondere Störungen abgewickelt werden.

Schlussfolgerungen

Die 1974 getroffene Entscheidung war der tatsächlichen Bausituation angemessen. Die Technologie auf diesem Sektor wurde um eine brauchbare Variante erweitert. Der Vorteil für die anbietende Arbeitsgemeinschaft war jedoch zeitlich begrenzt, der technologische Vorsprung durch die neue Methoden-Variante wurde im Wettbewerb schneller als angenommen wieder egalisiert.

Die bei der Ausführung gewonnenen Erfahrungen waren jedoch eine langfristige Bereicherung des Unternehmens-Potentials.

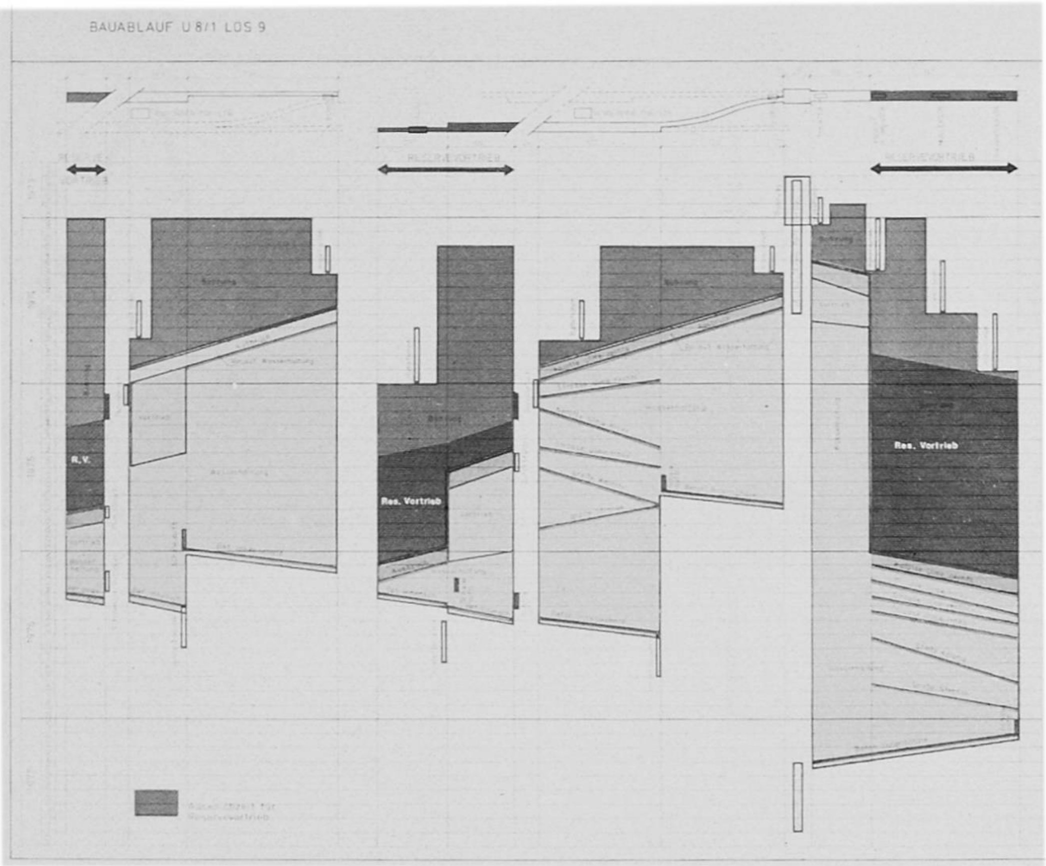

Bild 10: Volumen-Zeit-Diagramm

Bild 11: Mehrgleisiger Querschnitt