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THEME B

Engineering and Construction Management

Gestion du projet et de la construction

Management von Planung und Ausführung

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Innovation im Ingenieurwesen und Management

Innovation in Engineering and Management

Innovation en ingénierie et en gestion de projets

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Angelo Pozzi, geboren 1932, promovierte an der ETH in Zürich. Er war an mehreren Grossprojekten im In- und Ausland tätig; komplexe Führungsprobleme aller Art sind für ihn eine besondere Herausforderung. Seit 1971 ist er Professor für Projektmanagement und Baubetrieb an der ETH in Zürich. Heute ist er Vorsitzender der Geschäftsleitung der international tätigen Firmengruppe der Motor-Columbus AG.

ZUSAMMENFASSUNG
Wir verfügen über ein gewaltiges Innovationspotential, damit Projekte nutzbringender gestaltet, effizienter realisiert und ökonomischer genutzt werden können. Warum nutzen wir dieses Potential kaum; sind allenfalls die vielen Vorschriften und Normen zum Hindernis für neue Entwicklungen geworden? Warum planen und bauen wir kritiklos oft einfach das, was von Dritten gefordert wird; für das Resultat werden wir normalerweise verantwortlich gemacht. Wir müssen uns vermehrt mit den Projektkonzepten, den Projektzielen, der Projektökonomie und dem Projektmanagement befassen, die Innovation nachhaltig fördern und ihr mehr freien Lauf lassen. Wir brauchen ein günstiges Innovationsklima; wie schaffen wir das? An praktischen Beispielen sollen die Probleme dargestellt und die Lösungsansätze diskutiert werden.

SUMMARY
We dispose of an enormous innovation potential, enabling us to organize projects in a more effective way, to realize them more efficiently and to use them more economically. Why do we hardly make use of this potential; could it be that the numerous regulations and codes have become a barrier for new developments? Why do we plan and construct, mostly uncritically, simply following the requirements of others, even though we are aware that we will be held responsible for the result? We have to consider increasingly the project concepts, the project targets, the project economy, the project organization and the project management, promoting innovation effectively, and let it develop more freely. We need a climate favourable to innovation; how do we achieve this? The problems are demonstrated by practical examples, and possible solutions discussed.

RESUME
Nous disposons d'un important potentiel d'innovation permettant d'élaborer des projets de façon profitable, de les réaliser de manière efficace et de les exploiter économiquement. Pourquoi ce potentiel est-il si peu utilisé; les nombreuses prescriptions et normes sont-elles un handicap aux nouveaux développements? Pourquoi établissons-nous des projets et construisons-nous sans critique ce que les clients exigent, bien qu'après coup la société nous rende responsables du résultat? Nous devons nous préoccuper davantage de la conception des projets, de leur but, de leur économie, de leur élaboration et de leur gestion, favorisant efficacement l'innovation et lui laissant plus de liberté d'action. Nous avons besoin d'un climat qui encourage l'innovation; comment y parviendrons-nous? Les problèmes sont illustrés sur la base d'exemples pratiques et des éléments de solution discutés.

1. Introduction

I am of the opinion that civil engineering and we ourselves are getting into a cul-de-sac, that we have become *captives of our own successful past.* We have at our disposal an enormous knowledge and ability in the design and construction of individual facilities, especially their load-bearing structures. This will become particularly clear at this congress; structural enigineering has captured our imagination and through the possibility of computer support it has become even more fascinating, also for me. Through regulations, codes and standards our projects and the problem-solving processes have tended to become overregulated, we know a great deal about very many special problems. I have the impression, however, that we are contributing little towards the solution of problems which will decide the future, we seem to be not very interested, hardly prepared or motivated; perhaps many of us, due to the success in solving special problems, are no longer in a position to differentiate between the really important problems and those that are interesting, but less important.

Project management and *project engineering* must become more innovative if we want to be equipped for the *new tasks* which lie before us. I would like to urge you to concern yourselves more with these problems, to increasingly use your innovative skills and potential for the really important problems of the coming decades.

2. Successfull Past

We look back on a very successful development in the planning and construction of civil works. It was the *power of innovation* in our profession which made possible the enormous progress of civil engineering in the developed countries; *advances in materials* was to a large extent responsible for the decisive changes which occured. These were followed by new, time and cost saving *construction methods;* and in parallel a continuously improved understanding of the relationship between load and the behaviour of structures was developed. This led to even better model concepts and correspondingly to more refined *design methods.* This process is still in full swing, the benefit, however, has become smaller in relation to the cost and effort involved. The main problems no longer lie only in structural engineering as has been recognized for some time.

The bridging of rivers, valleys and bays was from the beginning a challenge to civil engineering. The changing requirements for living, work and communication have caused enormous developments in buildings and structures. The reliable supply of large regions with water, the production and distribution of sufficient quantities of energy, the waste disposal of highly populated regions, etc. has led to exacting demands on civil works of all types. Civil engineering today is at a level at which the existing technical problems can be solved with more than sufficient quality. I venture to doubt whether we also sufficiently well understand the overall systems of which civil works are part.

We have available today in the industrialized nations a large capacity for the planning and construction of civil works. In the last few decades we have carried out an immense volume of civil work. In a few industrialized regions the volume measured in real terms over the last 30 to 40 years has practically doubled (Fig. 1). As they age these civil works will have to be more and more intensively maintained and continually modernized. The need for civil works in these countries is to a sufficient extent covered, the demand for additional works will sink accordingly.

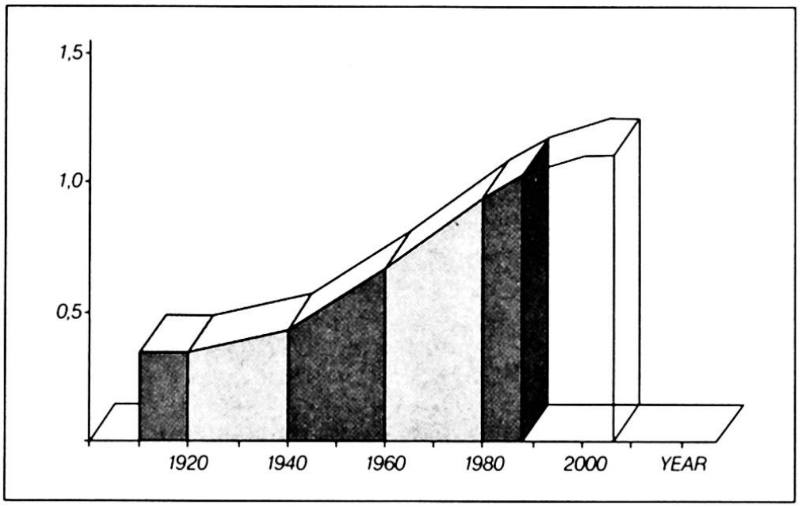

Fig. 1 **RELATIVE INCREASE IN VOLUME OF CIVIL WORKS**

In this boom phase over the last 30 to 40 years we have intensively developed civil engineering technology and brought it up to a high standard. And this in spite of serious mistakes being made time and again, time and cost schedules not being maintained, the quality and functional efficiency not corresponding to the planned objectives. This reflects the fact that *project management abilities have lagged behind the level of technical ability.*

3. Challenges of the Future

We face a challenging time in which novel, complex and decisive problems will have to be solved under time pressure. Our power of innovation will increasingly have to be turned towards the following problem areas "*management* of large projects", "understanding and improving the functional efficiency of *complex systems*" and "the optimal use of *available resources*". Civil, urban and rural engineering will have to make the most important contribution towards solving the problems which will arise through the increase and concentration of the world's population.

What actually will happen in the next 20 to 30 years? In the developed regions the population will stabilize at a level of approximative 1.3 billion (billion $=10^9$), this means it will not significantly increase compared with the present level of 1.1 billion. In the developing regions it will be a different story. In 1950 the population was 1.6 billion, in 1980 already 3.2 billion; the population is expected to again double in the period 1980 to 2020 and will then stand at some 6.5 billion (Fig. 2). This enormous development is accompanied by an increasing concentration of the population in urban areas (Fig. 3).

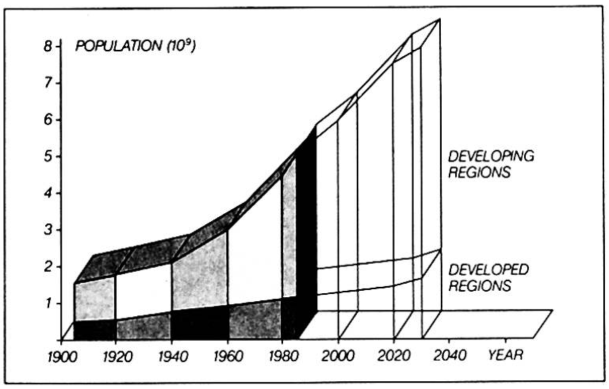

Fig. 2 **GROWTH OF POPULATION IN DEVELOPED AND DEVELOPING REGIONS**

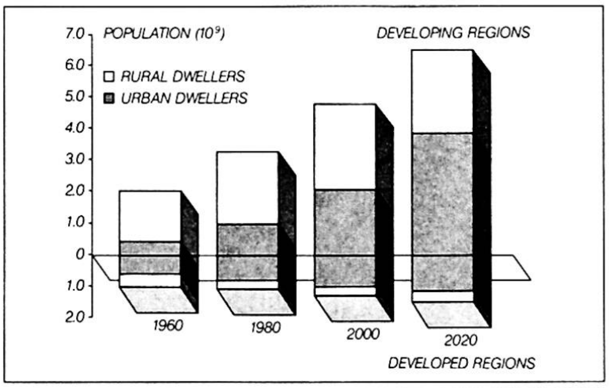

Fig. 3 **GROWTH OF POPULATION IN RURAL AND URBAN AREAS**

Although we had to some extent a grasp on this development in the last few decades, one can hardly say that for the future. On the basis of present forecasts the absolute increase in population in almost all parts of the world will be concentrated in towns. There will be an enormous influx of people from rural to urban areas incident to this increase in population (Fig 4).

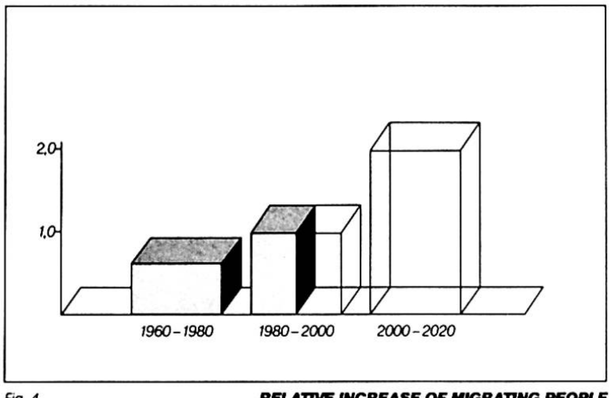

Fig. 4 **RELATIVE INCREASE OF MIGRATING PEOPLE INTO URBAN AREAS IN DEVELOPING REGIONS**

Expressed in another way, relatively fewer people must manage rural areas so that the rapidly increasing urban population can be supplied with sufficient food. For simplicity I would like to reduce this forecasted development to one single parameter, namely the number of new urban areas (Fig. 5). The new large urban areas with over five million inhabitants will practically all exist in the developing regions. That means: 200 to 300 new urban areas with over one million inhabitants will develop in the current 20-year-period of which about 20 urban areas will exceed five million inhabitants (Fig. 6).

		YEARS 1960	1980	2000	2020
>1 MIO	WORLDWIDE	100	200	450	1100
>5 MIO	DEVELOPED REGIONS	7	11	12	13
	DEVELOPING REGIONS	3	19	38	77
	WORLDWIDE	10	30	50	80

Fig. 5 **NUMBER OF URBAN AREAS**

	YEARS 1960–1980	1980–2000	2000–2020
NEW URBAN AREAS >1 MIO PEOPLE	100	200–300	500–800
NEW URBAN AREAS IN DEVELOPING REGIONS >5 MIO PEOPLE	15	15–25	30–50

Fig. 6 **NUMBER OF NEW URBAN AREAS**

The future brings a real *challenge,* because what happens in the developing regions in the next decades, is not without influence on the developed regions and vice versa; the interdependence will become increasingly greater. The main problems of the future will lie in the development of *well-functioning urban areas,* in the increase in the production capacity of *rural areas* and in the setting up of suitable *transport and communication systems.* The centre-of-gravity of the problems to be solved clearly lies in the developing regions.

4. Civil Engineering and Future Problems

What is actually new about the problems of the future? At first sight apparently little; we shall as before construct facilities so that sufficient water and energy is available in urban and rural areas; plan and construct so that *suitable space* for living accomodation, work and recreation is available; we shall plan and construct *facilities for traffic,* supply, waste disposal and communications, so that the required mobility, an acceptable *environmental impact* and the necessary flow of information is ensured. However, when we take the previously described developments into account then the requirements on these projects will really have to change.

In the developed regions the demand for new civil works as a result of the stabilizing population will decrease, the existing facilities will increasingly be modified through modernization requirements, the optimal utilization of the existing facilities will in the future still be a difficult task for civil engineering.

In the developing regions there will be an entirely different set of problems. The requirement for new facilities has already greatly increased and will further increase with the enormous increasing population and its concentration in metropolitan areas. In many urban areas current projects for new facilities cannot cover the demand by far, and this situation will get worse. Simple, suitable, practical solutions which can quickly be put into practice are called for.

We have at our disposal good methods and a high standard of civil engineering technology, when dealing with planning and construction of individual facilities. The deficiencies are noticed when the *overall systems and concepts,* the *masterplans,* are examined. Here we shall be challenged again, here we must apply our innovative potential; project management and project engineering will be the most important tools (Fig. 7).

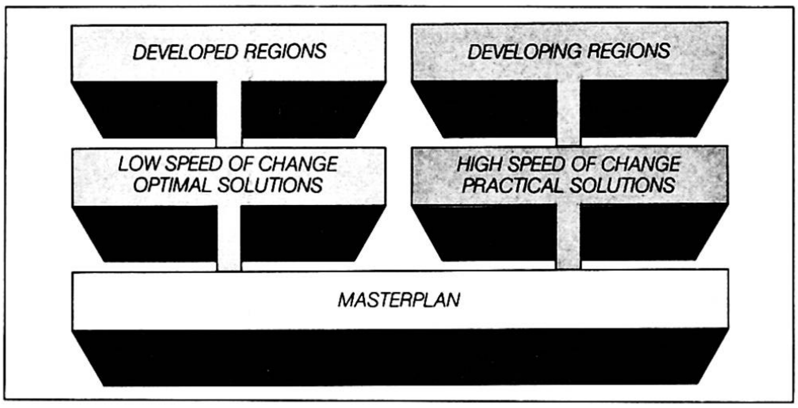

Fig. 7 **MASTERPLAN**

5. Project Management

Project management encompasses the systematic search, working out and realizing solutions for known and accepted problem situations; basically the project can arise from any particular problem area. With *project management* we guide a very complex *optimization process* between project, end-user, environment, project team and technology (Fig. 8). Certain rules are peculiar to each element, they determine the behaviour of the element. The rules of technology are well known to us, as far as planning and construction are concerned; we feel somewhat less certain about the laws which dictate the behaviour of the environment.

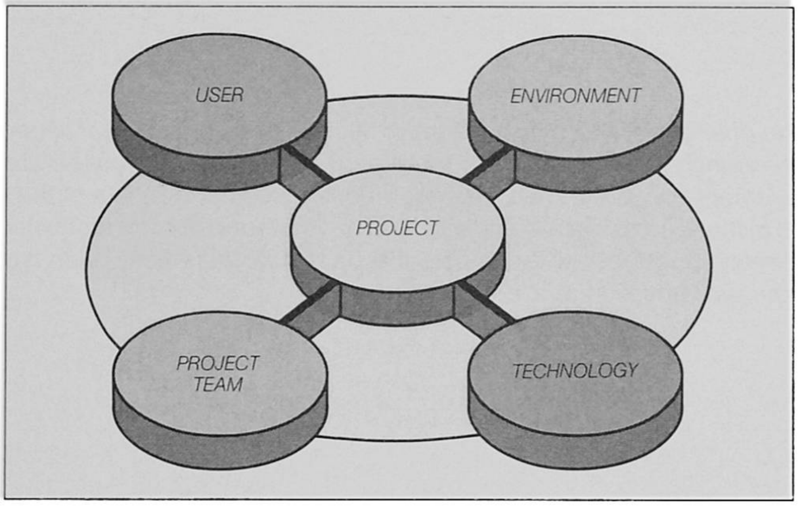

Fig. 8 **JOINT OPTIMIZATION PROCESS**

People take up an important position in this optimization process, they are involved as end-users as well as members of the project teams. They do not behave according to the rules of technology but according to the rules of psychology and sociology.

Each group of rules has its own peculiarities, limitations and possibilities, and it requires a high level of ability on the part of the project manager to control this optimization process taking into account the various rules of behaviour of the individual elements to achieve the required objective. It is not sufficient to design only one part of a system very carefully and then to expect that another part, which includes *people,* will adjust accordingly. Here the real problems are hidden, which always leads to difficulties. As examples one can refer to the increasing criticism by society of large technically sound projects, or as can be seen time and time again the failure of a project team to complete a project on time and within budget.

We must more intensively deal with the rules of all elements in the optimization process, in order that our projects are more well balanced. We must devote *more innovation towards project management* and not to keep it at arms length, only because technical problems are easier to solve.

6. Project Engineering

Project engineering is the art of working out a project comprehensively, taking into account *aesthetics, function, technology* and *economics* and to solve the related problems. Good project engineering ensures that a project as a whole, as well as in its individual parts, fulfils the applicable criteria.

Our projects are very much influenced by technical conditions; this is specially illustrated by the large number of codes and standards that have to be applied in a project. In addition, these codes and standards exhibit a high level of detail reflecting the very high standard of present technology.

In the education of engineers this dominance of technolgy is not without its drawbacks. Our engineers are extremely well educated from a technical point of view, and exactly for that reason the understanding and interest in creative, economic and operational problems is less well developed. This situation has various effects in practice. Most projects fulfil the technical requirements very well, the deficiencies are to be found in the non-technical requirements. Our innovative capacity is involved above all in the direction of technology so that as a logical consequence the development of project engineering goes the same way. This unbalance should be continually corrected. In education, project engineering including its fundamentals must be accorded a significantly higher priority than is the case at present. Project engineering must be intensively further developed, above all projects must be integrated into an overall concept or *masterplan*.

The development in micro-electronics, computer and simulation technology have opened new avenues for project engineering. One of the main problems of modern project engineering can be increasingly better solved, namely, to have for each project an objective-orientated and well functioning *project information system* available at the right time. With such a system the treatment of new, more complex projects can in time benefit much more from the groundwork and experience gained from previous successful projects. *Computer aided project engineering* allows a comprehensive treatment of projects, the quality of the projects will correspondingly increase.

7. New Tasks

We must re-adjust to the *changing character* of future projects. The *non-technical aspects* in the treatment of projects will become increasingly more important. It is imperative that the *education* of civil engineers is expanded and that *project management* and *project engineering* should become the tools of the engineer as much as mechanics. A relaxation of the rigid technical standards would allow more room for innovative solutions, *computer support* will create enormous possibilities whose potential up to now has hardly been tapped. Let us apply our *innovative capacity* in the right direction and let us do it now.

1. Einleitung

Ich bin der Auffassung, dass sich das Bauingenieurwesen und auch wir selbst in eine Sackgasse hineinbewegen, dass wir *Gefangene unserer eigenen erfolgreichen Vergangenheit* geworden sind. Wir verfügen über ein enormes Wissen und Können im Entwerfen und Ausführen von einzelnen Bauwerken, insbesondere deren Tragwerke. Gerade an diesem Kongress wird das besonders deutlich, «Structural Engineering» hat uns gefangen genommen, hat durch die Möglichkeit der Computerunterstützung an Faszination noch gewonnen, auch für mich. Wir haben durch Normen, Reglemente, Verordnungen und Gesetze unsere Projektumwelt und die Problemlösungsprozesse beinahe abschliessend geregelt, wir wissen viel über sehr viele Spezialprobleme. Ich habe aber den Eindruck, dass wir zur Lösung der zukunftsentscheidenden Probleme wenig beitragen, uns dafür wenig interessieren, kaum vorbereitet und motiviert sind; vielleicht sind auch viele von uns ob der Erfolge beim Lösen von Spezialproblemen nicht mehr in der Lage, das Wichtige vom Interessanten, aber weniger Wichtigen zu trennen.

Projektmanagement und *Projekt-Engineering* muss innovativer werden, wenn wir für die *neuen Aufgaben* gerüstet sein wollen. Ich möchte Ihnen einen Anstoss geben, sich selber mehr mit diesen Problemen abzugeben, also Ihr Innovationspotential vermehrt für die wichtigsten Probleme der kommenden Jahrzehnte zu engagieren.

2. Erfolgreiche Vergangenheit

Wir blicken auf eine sehr erfolgreiche Entwicklung des Planens und Ausführens von Bauwerken zurück. Es war die *Innovationskraft* unseres Berufsstandes, die die enorme Entwicklung der Bautechnik in den Industrieländern ermöglichte; für die entscheidenden Impulse waren weitgehend *materialtechnologische Neuerungen* verantwortlich. Ihnen folgten zeit- und kostensparende neue *Konstruktionsmethoden;* parallel dazu entwickelte sich ein laufend besseres Verständnis für den Zusammenhang «Belastung – Bauwerksverhalten», das dann wieder zu immer besseren *Modellkonzepten* und entsprechend verfeinerten Berechnungsmethoden führte. Dieser Prozess ist immer noch in vollem Gange, der Nutzenzuwachs ist aber im Verhältnis zum Aufwand kleiner geworden, die Hauptprobleme liegen zudem seit einiger Zeit erkennbar anderswo, nicht mehr im konstruktiven Bereich.

Das Überbrücken von Flüssen, Tälern und Meeresbuchten war seit jeher eine Herausforderung an die Bauingenieure. Die ändernden Bedürfnisse für Wohnen, Arbeiten und Kommunizieren haben enorme Entwicklungen im Bauwesen erzeugt. Die sichere Versorgung grosser Gebiete mit Wasser, die Erzeugung und Verteilung genügender Mengen passender Energie, die Entsorgung dicht besiedelter Regionen etc. hat zu anspruchsvollen Bauwerken aller Art geführt. Die Bautechnik ist heute auf einem Stand, bei dem faktisch die anstehenden Probleme mit mehr als genügender technischer Qualität gelöst werden können. Ob wir auch die den einzelnen Bauwerken übergeordneten Systeme genügend gut verstehen und beherrschen, wage ich zu bezweifeln.

Wir verfügen heute in den Industriestaaten über eine grosse Kapazität für das Planen und Bauen von Bauwerken. Wir haben in den letzten Jahrzehnten ein gewaltiges Bauvolumen bewältigt. In einigen industrialisierten Regionen hat die mit realen Geldwerten gemessene Bausubstanz in den letzten 30 bis 40 Jahren sich praktisch verdoppelt (Fig. 1). Diese Bausubstanz wird nun mit zunehmendem Alter vermehrt unterhalten und laufend modernisiert werden müssen. Das Bedürfnis nach baulichen Anlagen ist in diesen Ländern in ausreichendem Masse gedeckt, die Nachfrage nach zusätzlichen Anlagen wird entsprechend sinken.

Wir haben in dieser Boomphase die Bautechnik entsprechend intensiv entwickelt und auf einen hohen Stand gebracht. Dass trotzdem immer wieder manchmal auch grosse Fehler gemacht werden, Zeitpläne und Kostenprogramme oft nicht eingehalten werden können, die Qualität und Funktionstüchtigkeit der Anlagen den gesteckten Zielen nicht voll entsprechen, hängt damit zusammen, dass die *Managementfähigkeiten* der Projektbeteiligten deutlich *hinter dem bautechnischen Können zurückgeblieben sind.*

3. Herausfordernde Zukunft

Wir haben eine herausfordernde Zeit vor uns, in der neuartige, komplexe und entscheidende Probleme unter Zeitdruck gelöst werden müssen. Unsere Innovationskraft wird sich zunehmend auf die Problembereiche *Management* grösserer Organisationen, Verstehen und Verbessern *komplexer Systeme* und optimaleres Nutzen der *gegebenen Ressourcen* verlegen müssen, denn «Civil Urban and Rural Engineering» wird wohl den wesentlichsten Beitrag für die Lösung der Probleme leisten, die durch die einmalige Zunahme und Konzentration der Bevölkerung weltweit entstehen.

Was passiert eigentlich in den nächsten 20 bis 30 Jahren? In den «Developed Regions» wird sich die Bevölkerungszahl praktisch auf einer Höhe von ca. 1,3 Milliarden stabilisieren, also sich gegenüber dem heutigen Stand von ca. 1,1 Milliarden nicht mehr bedeutend erhöhen. Anders sieht dies in den «Developing Regions» aus. Betrug die Bevölkerungszahl 1950 noch ca. 1,6 Milliarden, so stand sie 1980 bereits auf ca. 3,2 Milliarden, sie wird sich aller Voraussicht nach in der Zeit von 1980 bis 2020 ein weiteres Mal verdoppeln und dann ca. 6,5 Milliarden betragen (Fig. 2).

Diese gewaltige Entwicklung wird von einer ständig zunehmenden Konzentration der Bevölkerung in Stadtregionen begleitet (Fig. 3). War diese Entwicklung in den letzten Jahrzehnten noch einigermassen überschaubar, so kann man das für die Zukunft kaum mehr sagen. Aufgrund der heute möglichen Prognosen wird der absolute Zuwachs der Bevölkerung in fast allen Teilen der Welt auf die Städte konzentriert sein, d.h. mit der Zunahme der Bevölkerung in den Städten ist eine gewaltige Völkerwanderung aus den Landregionen in die Stadtregionen verbunden (Fig.4). Das hat zur Folge, dass immer weniger Personen die Landregionen so bewirtschaften müssen, dass die rasch zunehmende Stadtbevölkerung genügend mit Grundnahrungsmitteln versorgt werden kann. Zur Übersicht möchte ich diese prognostizierte Entwicklung auf eine einzige Grösse reduzieren, nämlich die Anzahl neuer Städte (Fig. 5). Die neuen Stadtregionen mit über 5 Millionen Einwohnern werden praktisch alle in den «Developing Regions» entstehen. Das bedeutet: In der laufenden Periode 1980 bis 2000 wird sich die Anzahl der neuen Stadtregionen mit über 1 Million Einwohnern gegenüber der vergangenen Periode 1960 bis 1980 mehr als verdoppeln, davon werden neu ca. 20 Stadtregionen mehr als 5 Millionen Einwohner haben (Fig. 6).

Diese Zukunft bringt eine echte *Herausforderung,* denn das, was in den «Developing Regions» in den nächsten Jahrzehnten geschieht, ist nicht ohne Einfluss auf die «Developed Regions» und umgekehrt; die gegenseitige Abhängigkeit wird zunehmend grösser. Die Hauptprobleme der Zukunft werden im Ausbau *funktionstüchtiger Stadtregionen,* in der Erhöhung des Produktionspotentials der *Landgebiete* und im Aufbau angepasster *Kommunikationsmöglichkeiten* liegen, dabei liegt das Schwergewicht der zu lösenden Probleme klar in den «Developing Regions».

4. Neuorientierung in den Problemstellungen

Was ist denn eigentlich für uns neu an den sich in der Zukunft stellenden Problemen? Auf den ersten Blick scheinbar wenig; wir werden nach wie vor Anlagen erzeugen, damit genügend Wasser und Energie in Stadt- und Landregionen zur Verfügung steht; Hochbauten planen und erstellen, damit *passender Raum* für das Wohnen, Arbeiten und Erholen entsteht; *Verkehrs-, Versorgungs-, Entsorgungs- und Kommunikationsanlagen* projektieren und ausführen, damit die geforderte Mobilität, eine *vertretbare Umweltbelastung* und der notwendige Informationsfluss gesichert sind. Wenn wir nun aber die vorher dargestellten Entwicklungen als Basis nehmen, dann muss sich in den Anforderungen an diese Projekte doch Grundsätzliches ändern.

In den «Developed Regions» wird die Nachfrage nach neuen Anlagen infolge der sich stabilisierenden Bevölkerungszahl abnehmen, die bestehenden Anlagen wird man zunehmend durch Modernisierung den sich ändernden Bedürfnissen anpassen, die optimale Nutzung des Bestehenden wird in der Zukunft vermehrt die Planenden und Bauenden beschäftigen.

In den «Developing Regions» wird das Gegenteil eintreten, das Bedürfnis nach neuen Anlagen ist bereits stark gestiegen und wird mit der enormen Zunahme der Bevölkerung und der Konzentration in den Städten noch weiter steigen. In vielen Stadtregionen können die laufenden Projekte für neue Anlagen den Bedarf bei weitem nicht mehr decken, und diese Situation wird sich weiter verschärfen. Einfache, passende, rasch realisierbare und praktische Lösungen sind gesucht.

Wir verfügen über gute Methoden und einen hohen Stand der Bautechnik, wenn es um die Planung und Realisierung einzelner Bauwerke geht. Die Lücken spürt man erst, wenn man die *übergeordneten Systeme und Gesamtkonzepte, die Masterpläne,* überprüft. Hier werden wir neu gefordert, hier müssen wir unser Innovationspotential einsetzen, Projektmanagement und Projekt-Engineering werden die Hilfsmittel dazu sein (Fig. 7).

5. Projektmanagement

Projektmanagement umfasst das systematische Suchen, Erarbeiten und Realisieren von Lösungen für erkannte und akzeptierte Problemstellungen; grundsätzlich kann das Projekt irgendeinem Problemkreis entspringen. Mit *Projektmanagement* steuern wir eigentlich einen sehr komplexen *Optimierungsprozess* zwischen Projekt, Benützer, Umwelt, Projektteam und Technik (Fig. 8). Jedem dieser Elemente sind bestimmte Gesetzmässigkeiten eigen, sie bestimmen letztlich deren Verhalten. Die Gesetze der Technik sind uns gut bekannt, soweit sie beim Planen und Bauen zur Anwendung kommen; weniger sicher fühlen wir uns bereits bei den Gesetzen, die das Verhalten der Umwelt diktieren.

Menschen nehmen in diesem Optimierungsprozess eine bedeutende Stellung ein, sie sind als Benützer wie auch als Mitglieder des Projektteams aktiv. Sie verhalten sich nicht nach den Gesetzen der Technik, sondern gemäss den Regeln der Psychologie und Soziologie.

Jede Gruppe von Gesetzmässigkeiten hat ihre Besonderheiten, Einschränkungen und Möglichkeiten, und es braucht ein hohes Können der Projektleiter, diesen Optimierungsprozess unter Berücksichtigung der verschiedenen Verhaltensregeln der einzelnen Elemente zielgerichtet zu steuern. Es genügt nicht, nur den einen Teil des Systems sehr gründlich zu entwerfen und dann zu erwarten, dass der andere Teil, normalerweise der *Mensch,* sich anpassen wird. Hier sind die echten Probleme verborgen, die immer wieder zu Schwierigkeiten führen. Als Beispiele kann man die zunehmende Kritik an technisch qualifizierten Grossprojekten durch Benützer oder das immer wieder feststellbare Versagen eines Projektteams, ein Projekt kosten- und zeitgerecht zu realisieren, aufführen.

Wir müssen uns intensiver mit den Gesetzmässigkeiten aller Elemente des Optimierungsprozesses auseinandersetzen, damit unsere Projekte ausgewogener werden. Wir müssen *mehr Innovationskraft zugunsten des Projektmanagement* aufwenden und nicht davon Distanz nehmen, nur weil die technischen Probleme einfacher zu lösen sind.

6. Projekt-Engineering

Projekt-Engineering ist die Kunst, ein Projekt umfassend in *ästhetischer, betrieblicher, technischer* und *ökonomischer* Hinsicht zu bearbeiten und die damit verbundenen Probleme zu lösen. Projekt-Engineering stellt sicher, dass ein Projekt als Ganzes und in seinen wichtigen Teilen den entsprechenden Kriterien genügt.

Unsere Projekte werden sehr stark durch technische Bedingungen beeinflusst; dies zeigt sich insbesondere auch durch die sehr vielen technischen Normen, die in einem Projekt zur Anwendung kommen müssen. Diese Normenwerke weisen einen hohen Detaillierungsgrad auf, darin spiegelt sich der sehr hohe Stand der Technik wider.

In der Ausbildung der Ingenieure ist diese Dominanz der Technik nicht ohne Folgen geblieben. Unsere Ingenieure sind in technischer Hinsicht hervorragend ausgebildet, leider ist wohl gerade deshalb das Verständnis für Ästhetik, Ökonomie und Funktion wenig entwickelt. In der Praxis hat diese Situation verschiedene Wirkungen. Die meisten Projekte genügen den technischen Anforderungen sehr gut, den nichttechnischen Anforderungen jedoch zu wenig. Unsere Innovationskraft wird vor allem in Richtung Technik engagiert, so dass als logische Folge die Entwicklung des Projekt-Engineering denselben Weg geht. Die Verzerrung sollte nachhaltig korrigiert werden. In der Aus- und Weiterbildung muss Projekt-Engineering samt seinen Grundlagen mehr umfassen als dies heute der Fall ist. Projekt-Engineering muss intensiv weiterentwickelt werden, Projekte müssen in ein Gesamtkonzept oder *Masterplan* integriert werden.

Die Entwicklungen in der Mikroelektronik, der Computertechnik und der Simulationstechnik haben dem Projekt-Engineering neue Wege geöffnet. Eines der Hauptprobleme des modernen Projekt-Engineering lässt sich zunehmend besser lösen, nämlich für jedes Projekt ein zielorientiertes *Projektinformationssystem* zeitgerecht zur Verfügung zu haben. Damit kann man sich bei der Bearbeitung neuer, komplexer Projekte mit der Zeit besser auf die Grundlagen und Erfahrungen aus bestehenden, erfolgreichen Projekten abstützen. *Computerunterstütztes Projekt-Engineering* lässt eine umfassende Bearbeitung der Projekte zu, die Qualität der Projekte wird entsprechend steigen.

7. Neue Aufgaben

Wir müssen uns auf den sich *ändernden Charakter* der zukünftigen Projekte neu einstellen. Die *nichttechnischen Aspekte* werden in der Bearbeitung von Projekten zunehmend an Bedeutung gewinnen. *Aus- und Weiterbildung* sollten dringend angepasst werden, *Projektmanagement* und *Projekt-Engineering* sollten zum Werkzeug des Ingenieurs gehören wie zum Beispiel die Mechanik. Eine Lockerung der straffen technischen Normierungen würde mehr Freiraum für innovative Lösungen schaffen, die *Computerunterstützung* schafft enorme Möglichkeiten, wir haben das Potential noch kaum genutzt. Ein Engagement unserer *Innovationskraft* in dieser Richtung ist dringend notwendig.

The Honshu-Shikoku Bridges Project

Construction des ponts Honshu-Shikoku

Ausführung des Honshu-Shikoku Brückenbauprojektes

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SUMMARY
This paper discusses the implementation system for the construction of the Honshu-Shikoku Bridges, one of the biggest transportation projects in Japan. The area of responsibility of the public authority, the relationship with other organizations, funding, contract, execution of work and related problems are explained.

RESUME
L'article présente le système pour l'exécution de la construction des ponts Honshu-Shikoku, un des plus grands projets de transport au Japon. L'identification administrative du maître de l'ouvrage, la relation avec d'autres organismes, le financement, les contrats et l'exécution des travaux sont présentés.

ZUSAMMENFASSUNG
Diese Arbeit befasst sich mit dem Ausführungssystem des Honshu-Shikoku-Brückenbauprojektes, das eines der grössten Projekte auf dem Gebiet des Verkehrswesens in Japan darstellt. Die Zuständigkeitsbereiche der öffentlichen Verwaltung, die Beziehung zu anderen Organisationen, die Vergabe der Aufträge und Durchführung der Arbeiten usw. werden erläutert.

1. PREFACE

Japan is mainly composed of four islands (Honshu, Kyushu, Shikoku and Hokkaido), and the effort to link them by permanent transportation facilities has been made.
Shikoku faces Honshu through the Seto-Inland sea, and mild climate in and around the sea has gathered people to let them live there from the ancient time.
Current transportation between Honshu and Shikoku (transportation a day: 80,000 passengers and 230,000 ton of goods) is borne by ships and airplanes both vulnerable to bad weather. Transportation by ships requires longer hours, and growing traffic volumes of ships due to the economical development around the Seto-Inland sea has induced more frequent maritime accidents. Air service has only limited capacity.
Therefore, three routes of Honshu-Shikoku Bridges (H.S.B) have been planned to eliminate these disadvantages and to bring convenient life of people and well-balanced development of the area.
On the other hand, Honshu and Kyushu have been linked by a bridge and three undersea tunnels, and an undersea tunnel (planned completion 1986) has been drilled between Honshu and Hokkaido.

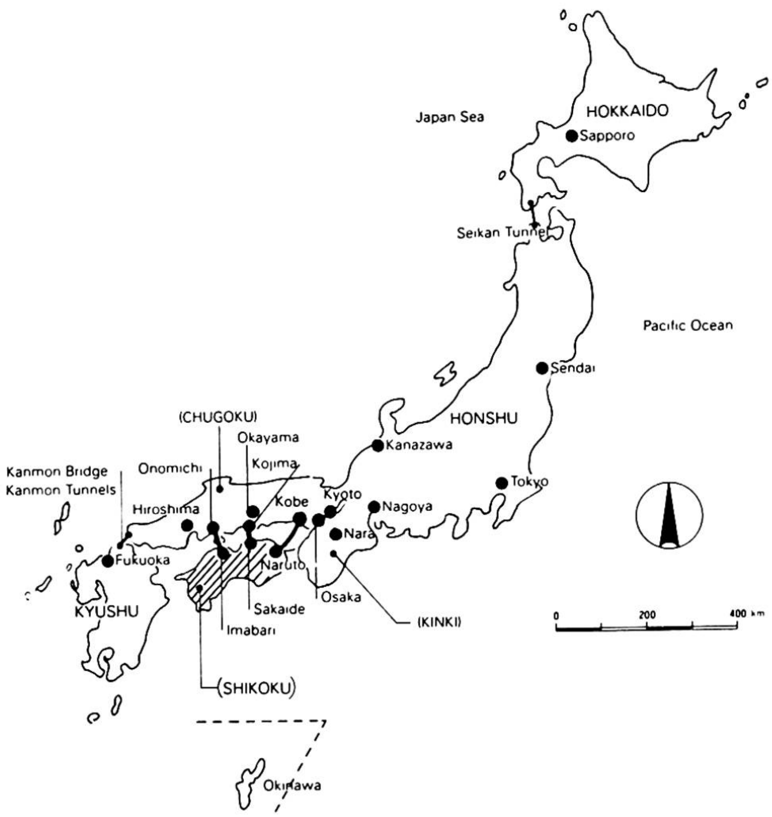


Fig. - 1 Japanese archipelago & 3 routes of the Honshu-Shikoku Bridge project

2. OUTLINE OF THE HONSHU-SHIKOKU BRIDGE PROJECT

Outline of the H.S.B. project is as shown in Table-1 and 2. Kobe-Naruto route and Kojima-Sakaide route are highway-railway combined bridges, and the latter railway is dual ordinary line and Shinkansen. Onomichi-Imabari route is only for highway. All the highways are expressways.
The project is currently carried out for Kojima-Sakaide route which is given the first priority by the government and other four bridges (Ohnaruto Br. in Kobe-Naruto route, Innoshima Br., Ohmishima Br. and Hakata-Ohshima Br. in Onomichi-Imabari route) which are judged to have strong regional developing effects, and Innoshima Br. and Ohmishima Br. among them have been put into service. This is called "1 route and 4 bridges policy" Japanese government has

Item	Category	Particulars	Kobe-Naruto	Kojima-Sakaide	Onomichi-Imabari
Length (km)	Highway		81.1	37.5	60.1
	Railway		89.8	32.4	-
Structural standards	Highway	Classification	Expressway	Expressway	Expressway
		Design speed (km/h)	100	100	80
		Number of lanes	6	4	4
	Railway	Classification	Shinkansen	Ordinary line and Shinkansen	-
		Number of tracks	2	2+2	-
Construction cost (billion yen)			1665	1110	585
Construction cost (billion US$)			7.24	4.83	2.54

(estimated in 1982, 1US$ ≒ 230 yen)

Table - 1 Summary of the project

Route	Name	Type	Span length (m)	Situation: Under construction	Situation: Completion	Year of completion
Kobe - Naruto	Akashi Kaikyo Bridge	Suspension	890+1,780+890			
	Ohnaruto Bridge	Suspension	93+330+876+330	○		1985
Kojima - Sakaide	Shimotsui-seto Bridge	Suspension	230+940+230	○		1988
	Hitsuishijima Bridge	Cable stayed	185+420+185	○		"
	Iwakurojima Bridge	Cable stayed	185+420+185	○		"
	Yoshima Bridge	Truss	175+245+165	○		"
	Kita Bisan-seto Bridge	Suspension	274+990+274	○		"
	Minami Bisan-seto Bridge	Suspension	274+1,100+274	○		"
Onomichi - Imabari	Onomichi Bridge	Cable stayed	85+210+85			
	Innoshima Bridge	Suspension	250+770+250		○	1983
	Ikuchi Bridge	Prestressed Concrete girder	150+250+150			
	Tatara Bridge	Suspension	300+890+300			
	Ohmishima Bridge	Arch	297		○	1979
	Hakata - Ohshima Bridge	Girder	90+145+90	○		1988
		Suspension	140+560+140			
	1st Kurushima Bridge	Suspension	80+190+860+194			
	2nd Kurushima Bridge	Suspension	110+550+110			
	3rd Kurushima Bridge	Suspension	260+1,000+260			

Table - 2 Main bridges in the project

ordered Honshu-Shikoku Bridge Authority (H.S.B.A.) to execute so far, because the financial situation of Japan has been tight after the oil-crisis in 1973. Fig.-2 shows all the bridges in straits section, highway-railway combined section, of Kojima-Sakaide route whose construction is enthusiastically conducted. The section continues for 13 km with sophisticated structures of various types. Railway service of this route for a while after the completion in 1988 will be limited for only the ordinary line.

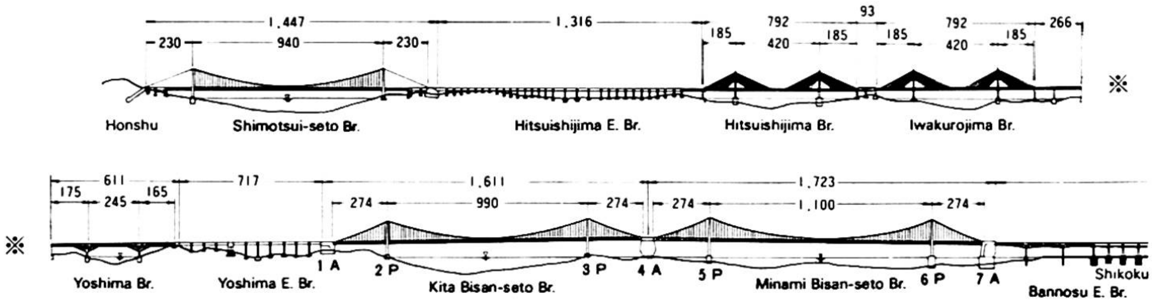


Fig. - 2 Side view of the bridges over straits of Kojima-Sakaide route

Technical characteristics of H.S.B. project are to construct long-span highway-railway combined bridges which are capable to sustain regular high-speed trains at straits with severe natural conditions such as sea-depth, tidal current, typhoon, earthquake, etc. (an example is shown in Table-3).

What enables this is long-lasting research and survey since 1955, which was first separately conducted by both sides of highway and railway but has been unitedly executed after the establishment of H.S.B.A. in 1970.

Sea depth at a site of a main pier	Tidal current speed at a main pier	Basic wind speed (10 minutes average at 10 m above the sea surface) *	Seismic acceleration at the base rock *
35 m (at 6P)	2.7 m/s (at 3P 4A & 5P)	43 m/s	180 gal

* recurrent interval = 150 years ∿ 100 years

Table - 3 Severe natural conditions for Minami & Kita Bisan-seto Bridges

3. IMPLEMENTATION SYSTEM FOR HONSHU-SHIKOU BRIDGE PROJECT

3.1 Identification of Honshu-Shikoku Bridge Authority

3.1.1 Background

Japan has two kinds of highway system. One is general free-highway managed by the Ministry of Construction or local governments with taxes, and another is toll-road which is constructed by an official agent with borrow money and whose borrowed money and interest are paid back from the toll. A big project which concentratedly needs great amount of money is often carried out as a toll-road. Table-4 shows the main toll-road systems in

Classification	Service area	Executing organization	Total planned extension *	Extention in service *
National expressway	Nation wide	Japan Highway Public Corporation	7,600 Km	3,400 Km
Urban expressway	In & around Tokyo	Metropolitan Expressway Public Corporation	250 Km	160 Km
	In & around Osaka	Hanshin Expressway Public Corporation	220 Km	120 Km
Honshu-Shikoku expressway	Between Honshu & Shikoku	Honshu-Shikoku Bridge Authority	180 Km	20 Km

As of Jan. 1984

All organizations are authorized by laws.

Table - 4 Main toll road systems in Japan

Japan. Trunk railways in Japan are operated by Japanese National Railways (J.N.R.) to which the facility constructed by H.S.B.A. will be rented.

3.1.2 Reasons and advantages of new establishment of H.S.B.A.

Long-lasting feasibility study revealed that the H.S.B. project was feasible and appropriate from viewpoints of engineering and national economy, respectively, and in 1970 the H.S.B.A. was newly established by a law as the executing body for the project. H.S.B.A. conducts as an official agent all affairs relating to the project such as planning, research and survey, design, order-superintendence-inspection of work, maintenance, funding, etc. under general directions from the government. And main advantages gained from such a manner to execute the project effectively are;

① The H.S.B. project is large in size and to construct long bridges at straits with severe natural conditions. Necessary technology in various engineering fields to construct the bridges can be integrated under a consistent responsibility by the single official agent.

② Although highway and railway belong to different administrative sections in Japan, combined bridges can smoothly be constructed and maintained without serious discrepancy under the single body which is able to adjust the both.

③ Great amount of money for the project is mainly funded as borrow money. The fiscal investment and loan funded by Japanese government is available, and the central and local governments locating in the region concerned can invest and subsidize the H.S.B.A., because it is an qualified official agent.

④ The H.S.B. will link trunk highways or railways in Honshu and Shikoku at the both ends and will greatly change the current traffic system. Cooperation and adjustment with the central and local governments can be facilitated to lessen the drastic change and to arrange effectively the access highways or railways which will function with the H.S.B.; and

⑤ So many people have lived in the narrow land of Japan, and the sea is also utilized for fishery or navigation. Various administrative measures necessary to execute the large project in such circumstances can be taken by the H.S.B.A. as an official agent.

3.1.3 Relationship with other organizations

During implementation of the project, the H.S.B.A. has various relationship whose scheme is idealistically shown in Fig.-3 with the central government, local governments, J.N.R., academic societies, private farms, etc.

Many engineers have traditionally belonged to owner official agents in Japan, and official agents have played stronger role than consultants or contractors throughout the entire phase of a project in many cases.

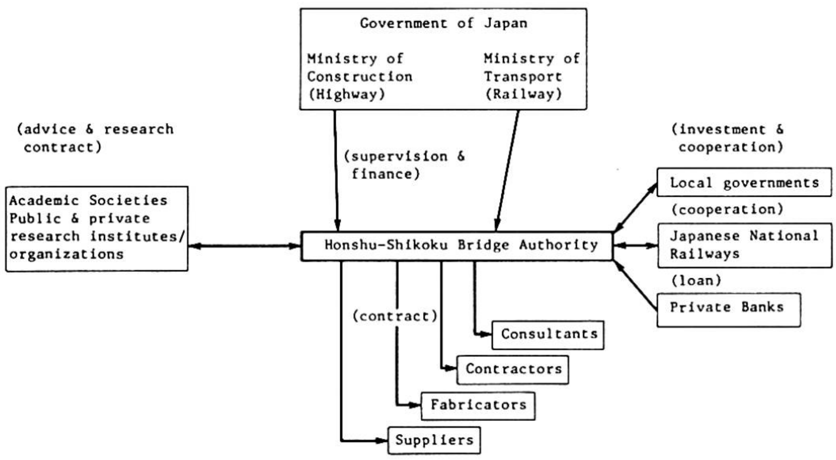


Fig. - 3 Relationship with other organizations

Table-5 shows the comparison between this in-house engineering method traditionally carried out in Japan and the conventional method widely applied in the U.S.A. or Western Europe. It should also be pointed out that insurance system for the public work is somewhat unperfect in Japan.

In the case of the H.S.B. project, stronger leadership of the owner than that for ordinary projects in Japan is required to adjust mutually different kinds of work from viewpoints of time and place, because the project has peculiar technical characteristics and complex concentration of type, schedule and place of the work and because a construction method is sometimes specified by the H.S.B.A. as described in 4.2.

Phase of the project	In-house engineering method			Conventional method		
	Owner	Consultants	Contractors	Owner	Consultants	Contractors
Feasibility study	○	△		△	○	
Decision of go/no go	○			○		
Final plan	○			○	△	
Detailed design	△	○		△	○	
Specifications	○			△	○	
Tender & checking tender documents	○		○	○	△	○
Construction & superintendence	○	△	○	△	○	○
Maintenance	○		△	○	△	△

Note, ○ : mainly conducted by
△ : subordinately conducted by

Table - 5 Comparison of engineering system

3.2 Organization of Honshu-Shikoku Bridge Authority

The H.S.B.A. is organized as shown in Fig.-4 to exert effectively the power, responsibility and demanded adjusting functions as described in 3.1. The head-office in Tokyo is conducting the planning and adjusting the project and common research. There are construction bureaus as intermediate managing organization in each route, and construction offices to engage construction work directly and a management office to maintain the opened facilities are arranged beneath the bureaus.

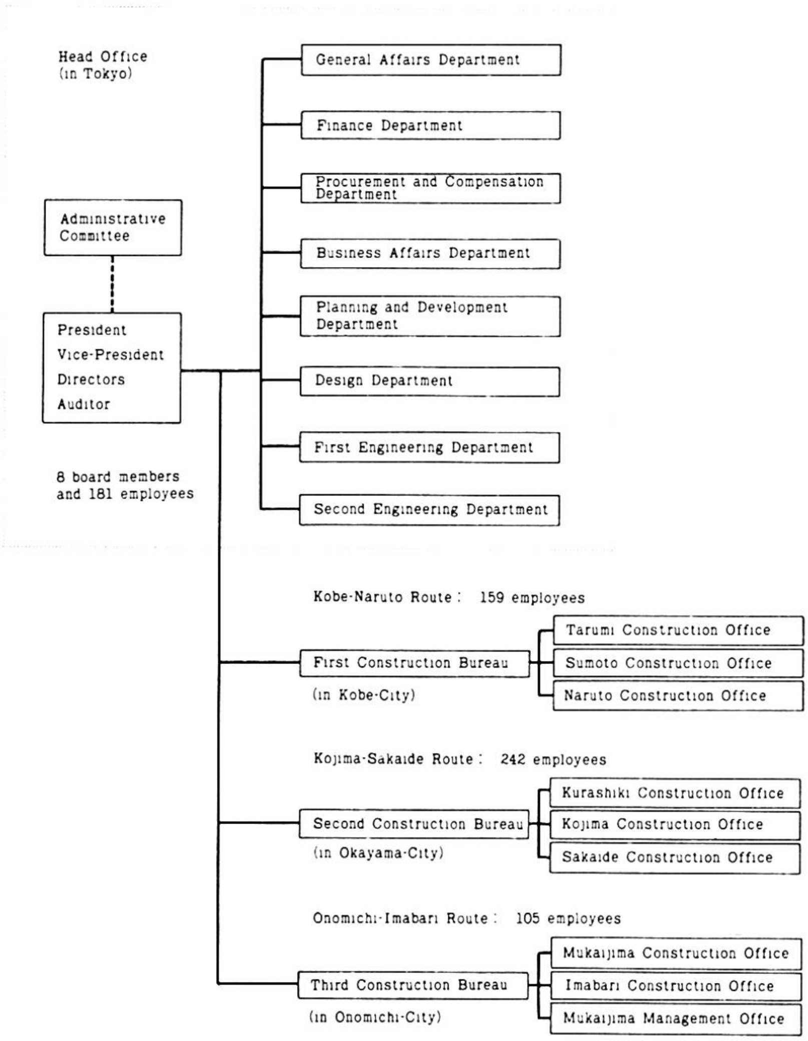


Fig. - 4 Organization of the Honshu-Shikoku Bridge Authority

Total man power of the H.S.B.A. is about 700 persons. Sixty percent of them are engineers whose speciality vary from civil engineering, geology, electronics, architecture, maritime affairs, climatology to environmental science. However, the H.S.B.A. has less man power compared with other organizations in spite of the size of the H.S.B. project.

4. EXECUTION OF PROJECT

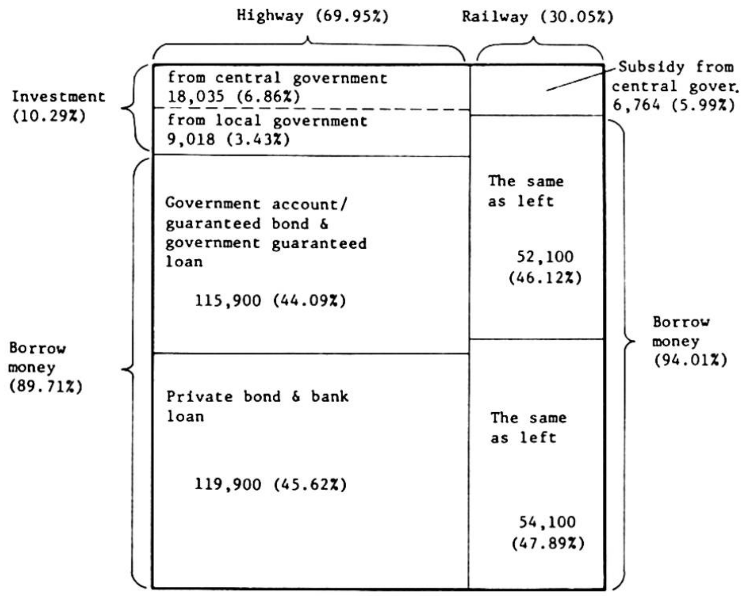
4.1 Funding and repayment

Annual budget of the H.S.B.A. is requested to the Ministry of Finance through both ministries of Construction and Transport, and comes into force after the budget draft which is submitted by the government based on the basic draft by the Ministry of Finance is approved by the National Diet. This procedure is common to all other governmental agencies.
Table-6 shows the expense budget for fiscal year (April to March) of 1984 when the construction of 1 route and 4 bridges reaches the climax. Although H.S.B. project is a combined project simultaneously carried out for highway and railway, the account is separately kept by a designated allocation method. Almost of all necessary money except investment or subsidy from the central or local governments is funded as borrow money as shown in Fig.-5.
All expense to construct and maintain the facility and its interest are paid back from the toll and the rental after the facility is opened for traffic. As for the H.S.B. highway, repayment will be finished by about 30 years after the opening on condition that the debt-cost i.e. effective interest is 6.15% and toll for the bridges over straits is fixed to approximately equal to the ferryboat charge. It is a common requirement for the toll-road project in Japan that the repayment can be finished within about 30 years against the debt-cost around 6%. In respect of the H.S.B. railway, suitable rental is going to be paid by J.N.R.

Items	Highway	Railway	Total
Construction, etc.	178,113	81,873	259,986
Maintenance & operation	467	-	467
Others	89,913	32,244	122,157
Total	268,493	114,117	382,610

Note: · Unit: million yen.
· Major part of others is payment of interest and re-funding for previous bond and loan.

Table -6 Expense budget for fiscal year of 1984



· Excluding toll revenue, etc. (6793).
· Unit: million yen

Fig. - 5 Revenue sources for fiscal year of 1984

4.2 Contract

Contract style for construction work of the H.S.B. project is the unit price contract with described total amount. In this contract, the unit price for every item which becomes basic unit for payment are established between the owner and the lowest bidder of the nominated competitive tender with several firms (or several joint ventures). During the work term, intermediate payment whose amount is determined from the sum of the contracted unit price multiplied by the completed quantity is made about four times a year. These inspection of the completed quantity and superintendence of the work are carried out by different engineers belonging to the H.S.B.A., but assistants are dispatched from contracted consultants to help day-to-day affairs of the superintendence.

Contract for public facility work of Japan generally contains the changed conditions clause that the contract can be modified when different conditions from those specified by the original contract are found, so, change of conditions of work, change of the quantity of work, etc. are frequently balanced. In addition, the cost over-run due to the inflation can be balanced. Therefore, these two balances are taken in the contract of the H.S.B.A., too.

Construction of long span bridges such as the H.S.B. project requires various kinds of work and long duration. Thus, a work which includes a group of sub-works well-bound from viewpoints of the schedule and place and whose term is about 2 to 4 years is usually ordered in one contract.

Guarantee of the quality of the work for the bridges over straits is required 10 years for the substructure and 5 years for the superstructure.

Choice of the construction method usually belongs to the contractor. However, in the case of the H.S.B. project which seems to challenge the limit of the civil engineering in the way of constructing huge structures at straits with severe natural conditions, the H.S.B.A. frequently specifies a construction method to which the H.S.B.A. can find reliability based on long-lasting research and survey. The contractor in this case is oblidged to execute this specified method. Although there are advantages as well as disadvantages in construction work by specified method, this is judged to be a good way for the H.S.B. project because of its technical characteristics.

In the next sub-chapter, an example of a work actually executed in the H.S.B. project will be discussed.

4.3 An example of work - undersea foundation works for Minami and Kita Bisan-Seto Bridges

4.3.1 Laying-down caisson method

Minami and Kita Bisan-seto Bridges are dual suspension bridges as shown in Table-2 and Fig.-2, and require 6 undersea foundations as shown in Table-7 from the viewpoint of bridge planning. As construction method for undersea foundations, the cofferdam method, the open-caisson method, the domed-caisson method, etc. have been conventionally available. However, these were judged to be unsatisfactory at the time of the feasibility study because they had difficulty to meet conditions such as water depth, geology, tidal current,

Items	2P	3P	4A	5P	6P	7A
Depth of water (m)	-10	-5	-5	-25	-35	-20
Foundation level (m)	-10	-10	-10	-32	-50	-50
Width (m)	57	57	62	59	59	59
Length (m)	23	23	57	27	38	75
Volume of excavation (m^3)	19,600	41,500	58,000	32,000	122,000	598,000
Volume of concrete (m^3)	13,000	13,000	36,000	49,000	105,000	235,000
Steel weight of caisson (t)	700	700	1,600	3,700	8,600	16,000

Note: Quantities of work is based on the laying-down caisson method.

Table - 7 Dimension and quantity of under-sea foundations for Minami and Kita Bisan-seto Bridges

dimension and setting depth of foundations and requirement of shorter term, and the laying-down caisson method was newly proposed.
The procedure of this laying-down caisson method is;

① Sea bed at the site is excavated until fresh and sufficiently strong bed-rock appears, and then the bedrock is smoothly and horizontally finished. During these excavations, whole shape of a steel caisson is built in a shipyard.

② The steel caisson being afloat or hoisted is transported to the site, and then is set at the designed position on the finished bedrock; and

③ Inside the caisson is filled with undersea concrete while the caisson acts as a form, and then the foundation is completed.

Various technical problems accompanying this method are solved as shown in Table-8 by research, survey and experimental work lasting more than 10 years and by integration of technical achievement in various engineering fields. And this method has been specified for 11 undersea foundations (including 6 of Minami and Kita Bisan-seto Br.s) out of 13 of Kojima-Sakaide route.

4.3.2 Execution of construction work

Because the quantity of works for 6 undersea foundations of Minami and Kita Bisan-seto Br.s is as huge as shown in Table-7, contracts were separately awarded to different joint ventures in the manner of 4 sections of (2P), (3P, 4A, 5P), (6P) and (7A).
On the other hand, fabrication of the steel caissons and the positioning system for setting caisson (composed of the automatic measuring system and the mooring system) were directly awarded to special firms (shipbuilders). These direct orders from the H.S.B.A. could make the quality of the caissons and the performance of the positioning system higher than they would be by the subcontract

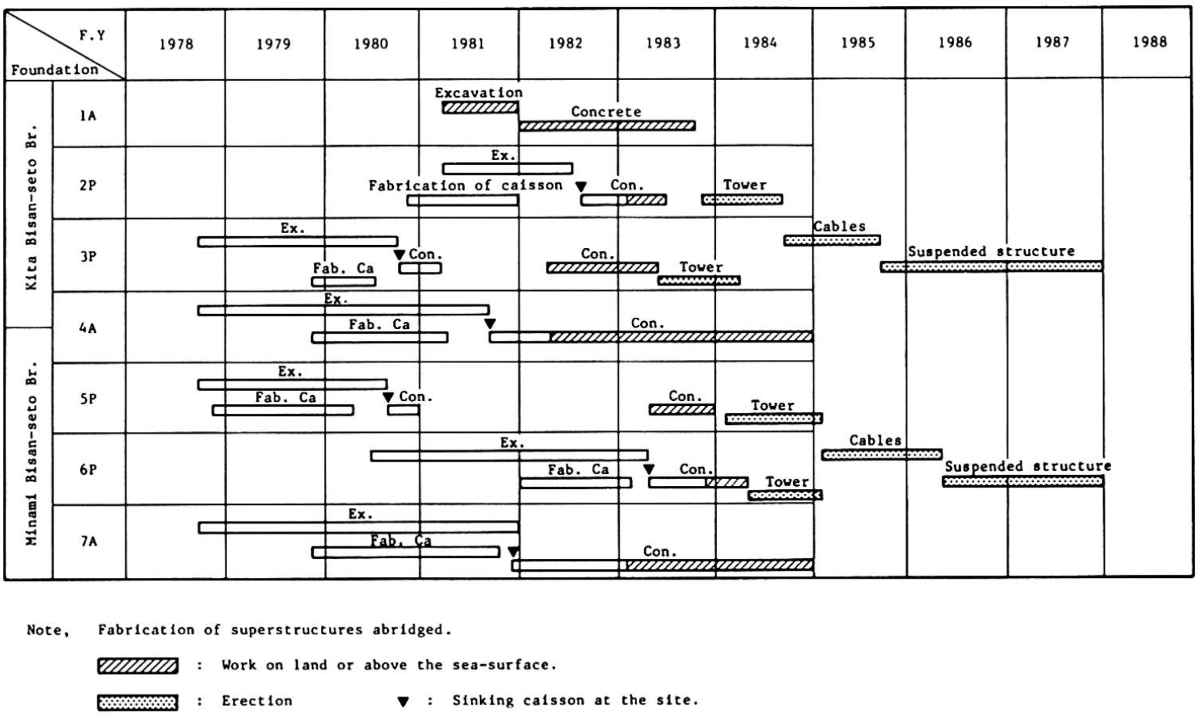


Fig. - 6 Actual/planned schedule for Minami & Kita Bisan-seto Bridges

Technical problems	Solution	Note
1 Underwater excavation	a) Underwater blasting up to 50 m below the sea level by S.E.P. (Self-Elevating Platform). The blasting is executed before the sediment atop the rock is removed to lessen the blasting shock to adjacent structures or fishes (The overburden drilling and blasting method).	• 3 kinds of detonation method are suitably selected.
	b) The sediment and cracked rock are excavated by large grab dredgers.	• Max. grab: 13 m^3
	c) Final surface of the bedrock is finished by large diameter drilling machine mounted on S.E.P.	• Achieved finished uneveness: a few c ntimeters
2 Underwater form and shore	d) The whole shape of a steel caisson which acts as form and shore is built in a shipyard, and then transported to the site, being afloat or hoisted by a floating crane.	
	e) The caisson is set at the designed position by the positioning system which composes of 8 winches and measuring devices for the location, draft, inclination, etc. of the caisson.	• Cap. of a winch: 130t • Mooring wires: 8-ϕ76mm • Weight of anchor blocks: 700 ∿ 900t • Achieved setting error: a few centimeters
3 Underwater concrete	f) By the prepacked concrete method. Specification for mix proportion of mortar, size and grading of the coarse aggregate previously packed, injection speed of mortar, interval of injection pipes for mortar, etc. were determined from a series of experiments.	σ_{ck} = 200 Kgf/cm^2
	g) A mortar plant burge capable to produce mortar of 360 m^3/hr (max.) is built and owned by H.S.B.A. to produce large amount of mortar continuously and stably.	• Usual capacity: 240 m^3/hr (equivalent to 500 m^3/hr of concrete)
4 Prevention of leakage of mortar from the gap between the caisson and the bedrock	h) Finishing the surface of the bedrock (by the method described in c)).	
	i) Rubber cushion is attached to the lower edge of the caisson, and around the caisson is previously sealed by the prepacked concrete.	

Table - 8 Technical development for laying-down caisson method

from the joint ventures. The mortar plant burge for the prepacked concrete was also constructed and owned by the H.S.B.A. and could be given the capacity of continuous-mass-production of the mortar, which in turn made it possible to cast the entire prepacked concrete of an undersea foundation unitedly from the bottom to the top without any horizontal junctions (1 to 7 blocks for casting were planely arranged depending on the plane area of foundations). The construction and the ownership of these two by the H.S.B.A. bring advantage to the redemption, because the redemption can be considered in the entire Kojima-Sakaide route.
In addition, production of the coarse aggregate of large diameter for the prepacked concrete and adjustment of grade and washing fine aggregate (sea sand) were separately awarded from the H.S.B.A., because the direct contracts made it easier for the H.S.B.A. to secure the quality and preservation of the environment. As for working bases, they are rented without charge from the H.S.B.A. which once borrowed them from the local governments who built.
As mentioned above, the H.S.B.A. separately awarded the prime works and the subordinate works, and could complete all the six undersea foundations in the duration between 1978 and 1983 as shown in Fig.-6 with lasting effort to secure the quality, schedule and safety as well as to adjust the relation between various works.
The organization in the H.S.B.A. directly in charge of these undersea foundation works was Sakaide Construction Office, the Second Construction Bureau. At the climax of the works, 15 engineers belonging to 3 sections of the above named office were engaged in superintendence with 24 assistants from 3 consultants.

5. CONCLUSION

The current construction work for 1 route and 4 bridges has been smoothly progressed so far by the implementation system described above, and at March 1984, digestion of the budget reached 51% of the total for 1 route and 4 bridges. In 1988, Honshu and Shikoku are going to be first united as expected.
The work for the left bridges belonging to other 2 routes are expected to start around 1988 when 1 route and 4 bridges are completed and to finish by the end of the 20th century. Among the left bridges, Akashi Kaikyo Bridge which will become the world's largest suspension bridge is included.

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Management of Large Projects in the Brazilian Amazon Region

Gestion de grand projets dans l'Amazonie Brésilienne

Management grosser Projekte im brasilianischen Amazonasgebiet

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SUMMARY
Brazil has one of the biggest hydroelectric potentials of the world. It is estimated to be of 213,000 MW, half of which is located in the Amazon Region. Eletronorte, a subsidiary of Eletrobrás, is the concessionary of this huge area of 4.7 million sq.km, which amounts to almost 58% of the total area of the country. This paper deals with the experience acquired by Eletronorte in managing large projects in this region from their early studies to their construction, focusing particularly the Tucurí Hydro Plant with a final installed capacity of 7,300 MW.

RESUME
Le Brésil a un des plus grands potentiels hydroélectriques du monde. Ce potentiel est estimé à 213.000 MW, dont la moitié se trouve dans la région amazonienne. Eletronorte, filiale de Eletrobrás, est concessionnaire de cette surface de 4.7 million km^2, qui correspond à environ 58% de la surface du pays. Le rapport présente l'expérience acquise par Eletronorte dans la gestion de grands projets hydroélectriques dans la région amazonienne depuis les études de sites jusqu'à la construction des usines, en particulier celle de Tucurui, qui aura une puissance installée finale de 7.300 MW.

ZUSAMMENFASSUNG
Brasilien verfügt über eines der grössten Wasserkraftpotentiale der Welt. Man schätzt es auf 213.000 MW, wovon die Hälfte sich im Amazonasgebiet befindet. Eletronorte, eine Tochtergesellschaft von Eletrobrás, ist der für dieses Gebiet zuständige Konzessionsnehmer. Dessen Oberfläche macht mit 4,7 Mio km^2 fast 58% der totalen Oberfläche des Landes aus. Dieser Aufsatz befasst sich mit der Erfahrung, die Eletronorte bei der Leitung von Grossprojekten gesammelt hat, von den Vorstudien bis zur Inbetriebsetzung. Besonders wird die Wasserkraftanlage Tucurui, deren Leistung beim Vollausbau 7.300 MW beträgt, ins Blickzentrum genommen.

1. INTRODUCTION

The geographic conditions of Brazil - its tropical climate, its large territorial area and hydrographic systems - and the country's relative scarcity of fossil fuel reserves have caused the planning of the national energy system to be based, from its very start, on the development of the nation's large hydroelectric potential.

The importance of this approach was enhanced by the succesive oil crises, which showed the dangers of being dependent on non-renewable fuels, specially if they have to be imported.

Within this policy ELETRONORTE, founded in 1973, continued the program of inventories of the Amazon Region basins, which was started by ELETROBRÁS 10 years before, and which is still going on. Up to this moment, 1,300,000 sq.km have been investigated, with 65 sites identified for hydroelectric purposes, totalling 46,000 MW. At this moment, the company hàs three plants under construction: Balbina, on the Uatamã river in the state of Amazonas, with 250 MW; Samuel, on the Jamari river in the state of Rondônia, with 220 MW; and Tucuruí, on the Tocantins river in the state of Pará, with a final capacity of 7,300 MW (4,000 MW in its first stage).

In order to develop this hydroelectric potential, special techniques for inventory, design and construction had to be developed by ELETRONORTE. These techniques are based on the experience of the Brazilian energy sector in power macro-planning, and on the cumulative experience with large hydroelectric plants and huge transmission systems obtained through the various projects built in the country during the last 20 years under ELETROBRÁS coordination.

In order to explain the causes of the management procedures which were created, developed and implemented by ELETRONORTE, we need to present a brief summary of the macro-geographic and environmental conditions which have determined the methodology adopted by the company.

2. BACKGROUND ON HYDRO POTENTIAL IN THE BRAZILIAN NORTH AND NORTHEAST

The Amazon river basin is one of the biggest in the entire world. It receives water from the three potamographic systems. The first of these is the West system, which comes from international basins whose headwaters are located in Bolivia and Peru. The second one is the Brazilian Extreme-North system, with headwaters in the highlands on the borders of Brazil with Venezuela, Colombia, Suriname and the Guianas. The third one is the South system, whose water comes from the Brazilian Central Plateau.

This Plateau, with altitude levels ranging from 500 m to 1,200 m above the sea level, separates the two main hydraulic basins of Brazil, namely, the Amazon basin and the Prata basin. Besides containing the headwaters of important right bank tributaries of the Amazon river, it also contains the headwaters of another important and independent basin: that of the São Francisco river, which flows into the Atlantic Ocean in the Northeast coast of Brazil, between the states of Sergipe and Alagoas. This river contains, already in operation, the Paulo Afonso and Sobradinho generation system, with an installed capacity of 5,231 MW. It also contains the 2,500 MW Itaparica plant (under construction), and the 5,000 MW Xingó plant (under study).

All the hydro potential of the country's Northeast region is located on the drop of the Brazilian Central Plateau to the Atlantic Ocean, and part of the potential of the country's North region is on the drop of the same plateau to the Amazon plain. Two companies, both of which are subsidiaries of Centrais Elétricas Brasileiras S.A. - ELETROBRÁS, have the concessions corresponding to this potential. The oldest of these is Companhia Hidroelétrica do São Francisco -

CHESF, founded in 1945; and the newest is Centrais Elétricas do Norte do Brasil S.A. - ELETRONORTE, founded in 1973.

Presently, by means of a special agreement, CHESF supplies the state of Pará, in the North region, through ELETRONORTE's pioneer 500/230 kV system, which is part of the Tucuruí project. This transmission system was anticipated in order to supply the cities of Belém and Imperatriz and the Tucuruí plant construction site with hydroelectric power, replacing local thermal generation based on fossil fuels, for both base and peak loads. As a result, the total outlay on ELETRONORTE's thermal plants, which in 1980 was 269,908 cubic meters of diesel oil and 442,832 tons of fuel oil, corresponding to a disbursment of US$ 164.2 million, has been reduced by 55% in terms of cost, through the use of the anticipated line of the Tucuruí transmission system.

The growing interest in major mining projects and electro-metalurgical industries in the Amazon Region for national development, was further increased by the possibility of transmission of the energy generated in the region to the industrial markets of the Brazilian Southeast region.

3. THE BRAZILIAN EXPERIENCE AND THE AMAZON PROJECTS

The evolution of management of design and construction within the Brazilian electric sector may be divided in three periods, the first of which corresponds to a pioneering phase, in which planning and construction were executed by foreign companies. In practice, the system covered only the areas around the cities of Rio de Janeiro and São Paulo, with local service for other state capitals. It used mixed hydro and thermal generation with short transmission lines.

The second period began in 1946, with the creation of Companhia Hidroelétrica do São Francisco - CHESF, by the Federal Government. Planning started to be done on a regional basis, and design and construction were characterized by vertical management and executive structures. This was due both to the country's stage of development at the time, and also to the specific socio-economic conditions of the Northeast region of Brazil. During this period, CHESF used its own personnel to perform all the activities of planning, design, construction and control of its hydro and long transmission lines projects.

The third period began with the creation of Centrais Elétricas de Minas Gerais S.A. - CEMIG, in 1952. This period brought about the first changes which limited the company's role in design and construction. These changes opened opportunities for private companies in the areas of consulting engineering and job contracting.

The planning policy of the Brazilian electric sector has been under application since the early sixties, when Brazil started a comprehensive and systematic study of its vast potential. This was due to the results of planning studies done by Canambra Engineering Consultants Ltd. for the South-Central and Southern regions of Brazil, which were followed by other planning studies done by the ELETROBRÁS study committees ENERAM and ENENORDE, respectively for the Northern and West-Central and for the Northeastern regions. These studies were done with the support of Brazilian enterprises.

From this point on, as a function of the long construction times and great size of Brazilian hydro projects, and using the experience of CHESF and the newer concessionaries, the Brazilian engineering private companies began to have greater participation with the studies, starting in the area of design and extending progressively to management of the main power plant and transmission system projects.

4. THE JOB TO BE DEVELOPED ON SITE UNDER AMAZONIC CONDITIONS

In order to study and build electricity generation projects in the Amazon region, ELETRONORTE has been performing, since it was created, a large study program, which includes many uninhabited and distant areas, and covers 58% of the Brazilian territory. This area has an immense potential, which is evidenced by the very large mining, metalurgical, agricultural, livestock and forestry projects which are being started in it. Of special note are the projects for developing the enormous mineral reserves of the Carajás region, the bauxite reserves further north, and agricultural areas, mainly in the states of Rondônia and Mato Grosso.

ELETRONORTE has been studying the hydroelectric potential of the river systems in its area of activity. This potential amounts to roughly 100 GW, not including the Amazon river itself. Special attention has been given to the Tocantins river system, where the studies have indicated a potential of 25 GW, to be obtained through 15 plants whose feasibility studies have been completed. One of these projects is already being built, the immense Tucuruí hydro plant, with 4,000 MW in its first stage and 7,300 MW after its full completion. In order to attain these results, it is necessary to establish conditions which make the corresponding jobs feasible to private consultants.

Special consideration has to be given to the difficulties of conducting technical activity in a jungle environment, including topographical geodesical, geological, hydrological and ecological studies,with their requirements of equipment, personnel, food and other supplies. This in turn leads to complex logistics, including land, air and water transportation, and also requires radio communications and other items in order to provide a link between field and office project activities.

It must be considered that these activities take place at sites which are from 1,500 km to 2,000 km distant from Brasília, São Paulo and Rio de Janeiro, where the main consulting companies, which have the technical ability and financial capacity to perform these studies, are located. Sometimes the field studies have the appearance of complex military operations, involving planes, helicopters, motorboats, and special vehicles which are able to cross swamps and uneven lands. All of this takes place in the region which has the lowest level of economic activity in Brazil, with a population density of 1.1 inhabitants per sq.km, while the rest of the country has a density of 30 inhabitants per sq.km.

5. THE EXPERIENCE OF ELETRONORTE

ELETRONORTE has always reserved for itself the general coordination of the planning phase of its projects, and considered that their operation should be its main statutory objective. It has reserved for private companies the execution of the planning phase of the projects, and their design and construction. It was able to profit from the experience of its older congenerous companies in order to establish a new line of action, which is adapted to its special responsibilities as the concessionary for the generation and transmission of large amounts of energy in the Amazon region.

The environmental conditions of the area, added to its long distances and lack of population,with the attendant problems of isolation and logistics, have led ELETRONORTE to the formulation of principles which are based on the precept of "unity of responsibility with maximum delegation".

5.1 The Meaning of this Precept

The various risks which have to be taken during the execution of any project in the Amazon region, certain special difficulties which will be commented in later paragraphs, the need to offer private consultant firms stimulating conditions for participation, and the need, above all, to be sure of receiving the best possible service, have led ELETRONORTE to adopt this precept, which in practice translates into: "The ones that do the inventory should also do the design and oversee the construction with the maximum participation of the consulting companies". In this way, all the steps are carried out under constant and rigorous supervision by ELETRONORTE,which counts with strong participation of consulting firms from the very beginning of the projects. In this way, these companies have a strong incentive to execute each of these steps-inventory, feasibility, and basic studies, which precedes the public licitation for construction - in the best possible way, and to conclude them on time, as prescribed by the contracts.

On the other hand, the use of consulting companies to perform these activities, instead of ELETRONORTE's own staff, avoids the surpluses of technical personnel within ELETRONORTE which would occur between the conclusion of each project and the beginning of the next one.

The optimization of design and construction is garanteed by the ELETRONORTE people, as the former of these is accompanied, and the latter supervised, by them. In practice, this leads to the creation of two areas within the group in charge of the project, which are inter-related, and which complement each other in the following ways:

- The inspection group, which demands that blueprints and specifications of high quality be sent on time, in order to avoid loss of time due to their lack;

- The design group, which demands that the field group follow the specifications as closely as possible.

This interaction forces the group as a whole to achieve a greater degree of efficiency, under the principle of "unity of responsibility".

5.2 The Application of the Principles

This principle is in full application in all ELETRONORTE's projects. These projects are listed below, together with the symbol (1) for projects under construction, (a) for projects whose feasibility is being studied, and (b) for projects in the basic studies stage:

PROJECT	INSTALLED CAPACITY (MW)	RIVER	STATE
(1) Tucuruī	4,000 plus 3,300	Tocantins	Pará
(1) Balbina	250	Uatamã	Amazonas
(1) Samuel	220	Jamarī	Rondônia
(a) Babaquara-Kararaõ	14,000	Xingū	Pará
(b) Santa Isabel	2,400	Araguaia	Goiás
(b) Porteira	1,400	Trombetas	Amazonas
(b) Manso	210	Manso	Mato Grosso

5.3 The 7,300 MW Tucuruī Power Plant on the Tocantins River

The main example of the application of these principles is Tucuruī, which is the second largest power plant in Brazil, located on the Tocantins river, 300 km south of Belém, which is the capital and most important city of the state of Pará. The principles are being applied by ELETRONORTE with a consortium formed by Themag Engenharia S.A. and Engevix Engenharia S.A. (both consulting companies) and the civil works contractor Construções e Comércio Camargo Corrêa S.A.

The main characteristics of the Tucuruī project may be described shortly as: final capacity of 7,300 MW with 330 MW units, under a nominal head of 60.8 m; - 45.8 km^3 of total accumulated volume in the reservoir, with 25.4 km^3 of useful volume; - 576 m^3/s of turbine flow under nominal head with 83.7 rpm; - 94,500 m^3 of ordinary and back fill excavations; - 5,700,000 m^3 of concrete and 19,000,000 m^3 of coffer dams.

6. THE TUCURUÍ POWER PLANT CONSTRUCTION MANAGEMENT

The management activities for the construction of the Tucurui power plant are characterized by the fact that the consultant has been present since the early phases of the project. All work is done under ELETRONORTE supervision and control, and this process has resulted in a light management structure. The process itself is described by the flowcharts in this chapter. The content of these flowcharts can be summarized as follows:

6.1 Flowchart I - Engineering Studies

This flowchart shows the procedures for initial approval of the feasibility studies under the coordination of ELETRONORTE's Planning Department, their final approval by ELETROBRÁS, and also the corresponding procedures for the initial and final approval of the basic design under coordination of ELETRONORTE's Project Department.

6.2 Flowchart II - Civil Works and Electromechanical Assembly

This flowchart outlines the main aspects of technical and administrative control for civil works and electromechanical assembly. It begins with the establishment of technical specifications by ELETRONORTE, which led to the choice of the main civil works contractor, and also to a state protocol signed by the Brazilian Government and the French Government for the acquisition of electrical and mechanical equipment. The fact that 20% of the equipment is made in France and 80% is made in Brazil has resulted in the inspection and quality control structures shown by the flowchart, which also presents the areas of responsibility of the consultant and of ELETRONORTE when changes in design are needed after the execution of the whole project has started.

6.3 Flowchart III - Purchase of the Power Plant Equipment

This flowchart shows the main relationships between ELETRONORTE and the consultant in the purchase of equipment. It defines the main responsibilities in cost control, quality control and transportation, based on equipment specifications prepared by ELETRONORTE.

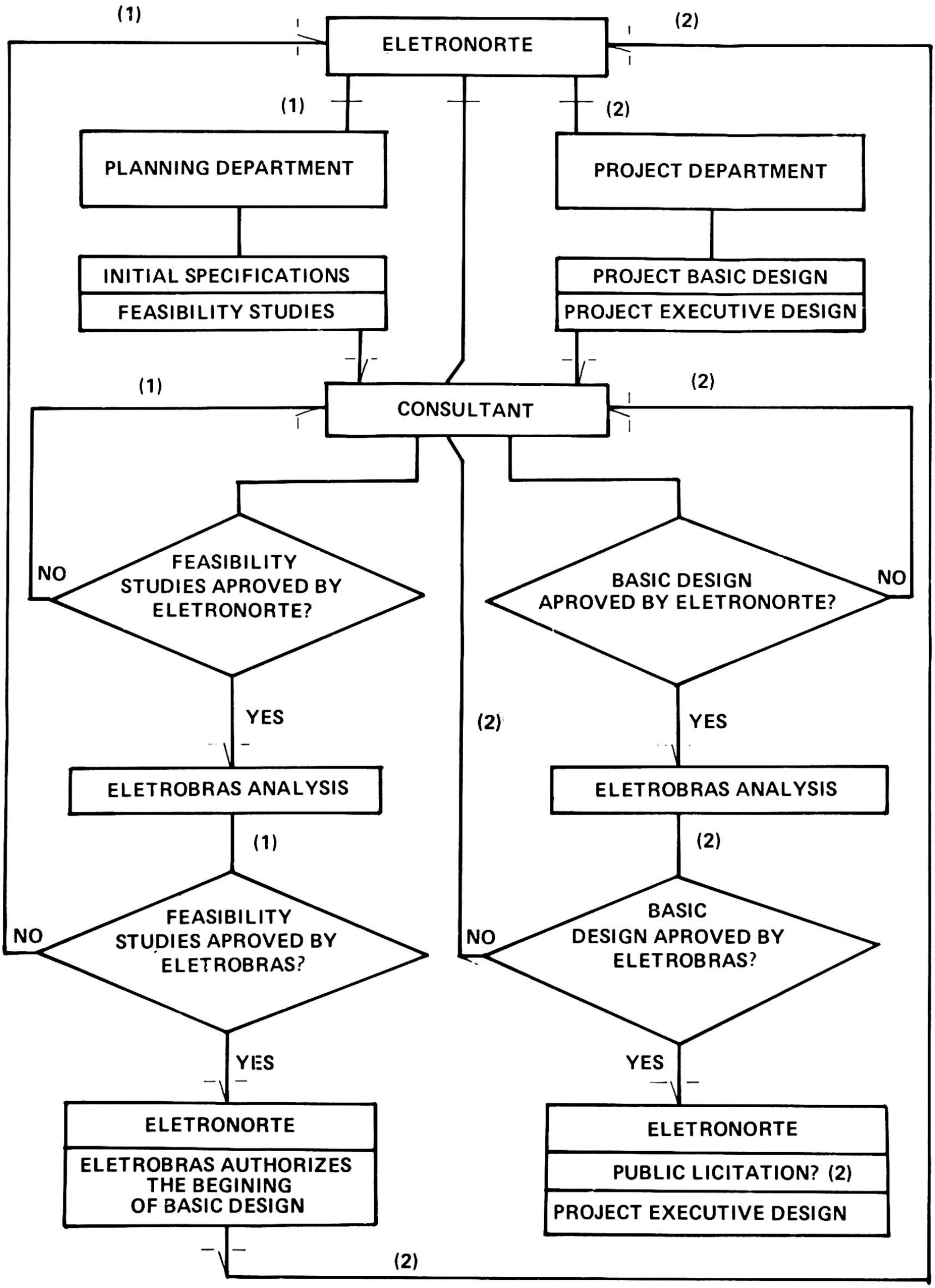
7. THE PRACTICAL APPLICATION OF THE PRINCIPLES

Once the planning phase of hydroelectric project is finished, the execution of the project requires that its basic components, namely,engineering design, choice of equipment, public licitation and signing of contracts for construction and assembly, be started at the same time.

7.1 The Graphic Representation of the Process

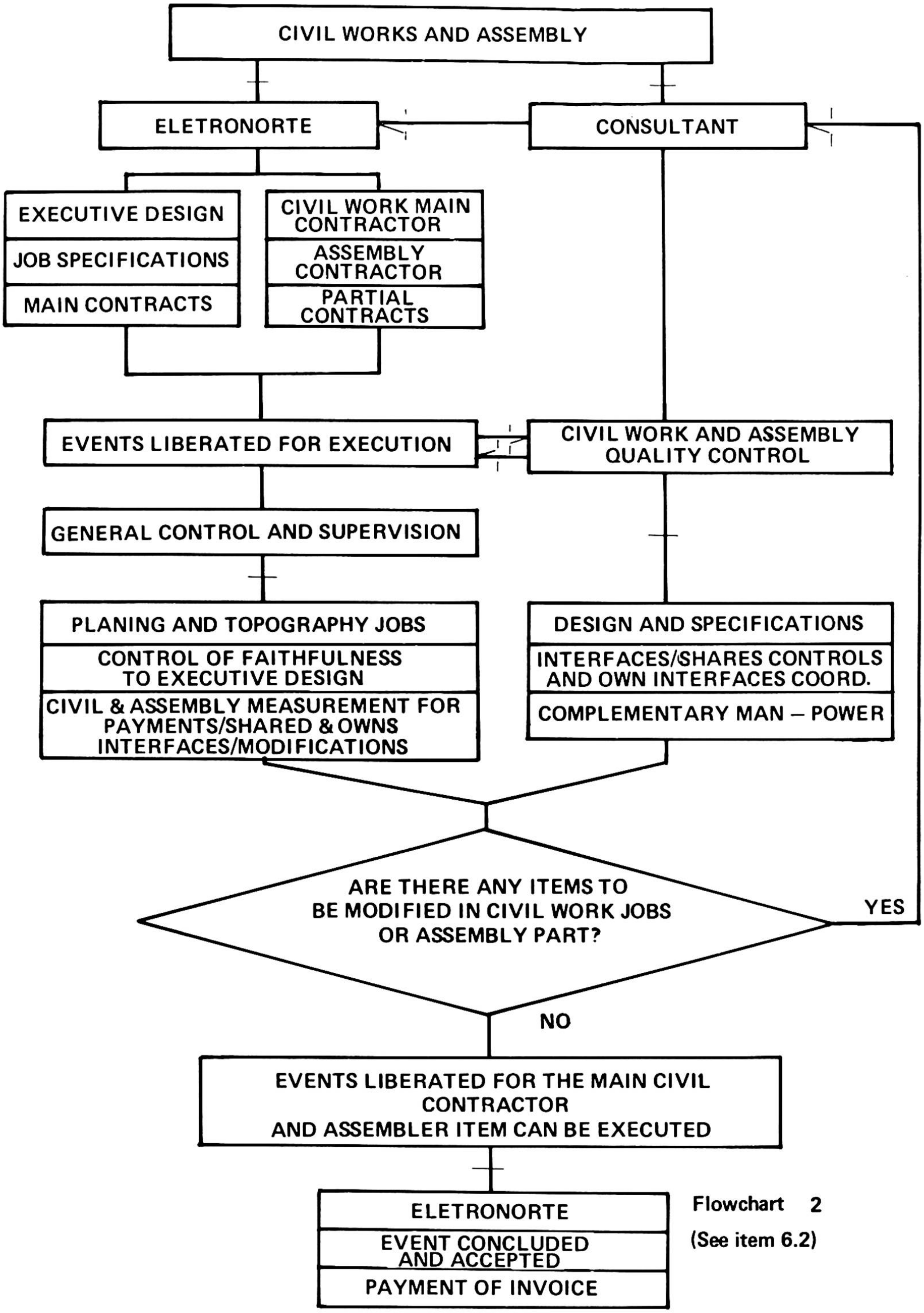
Using Prof. Ladi Biezus' notation, the management of the Tucuruí project can be represented by the five circles in figure 1. The outermost circle represents planning. Inside this circle are three other circles, denoted "P", "O" and "E". The "P" circle represents engineering design activities; the "O" circle, civil works and assembly activities; and the "E" circle, activities related to the equipment. These three circles have areas in common, as the corresponding activities do during the execution of the project. The innermost circle (shaded area in figure 1), represents internal activities, corresponding to actual construction and services.

The area which is not shaded in figure 1 represents conceptual activities, coordination activities, and management activities.



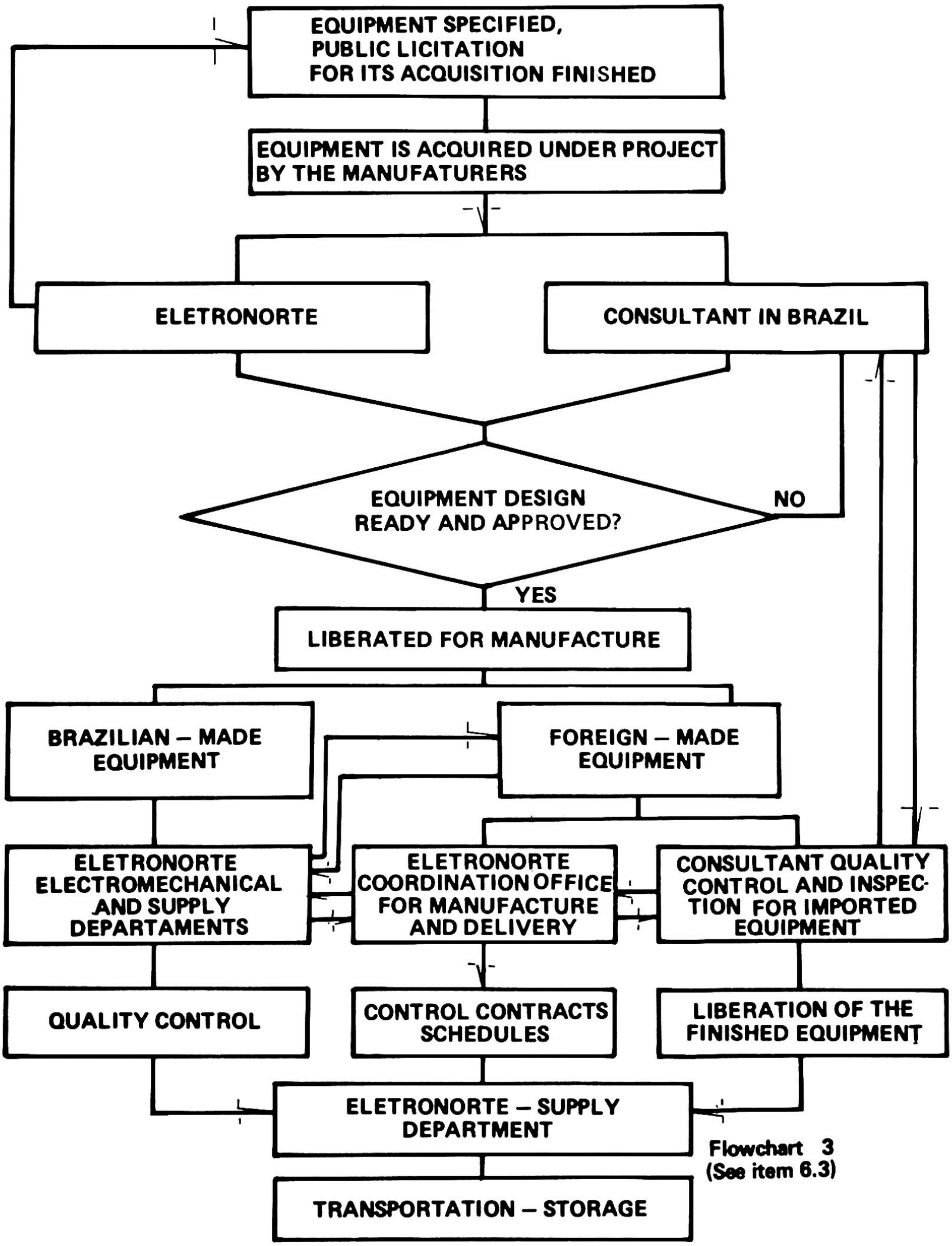
TUCURUI POWER PLANT
APPROVAL OF FEASIBILITY AND DESIGN

Flowchart # 1
(See item 6.1)



Flowchart 2

(See item 6.2)



Flowchart 3
(See item 6.3)

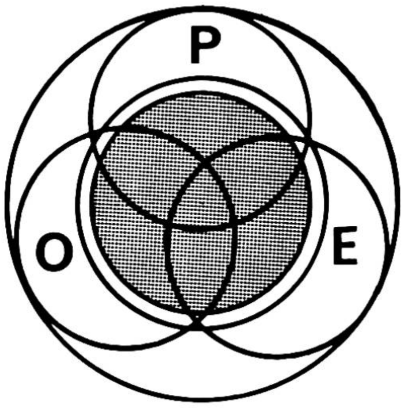


Fig.

Figure 1

A good coordination of all these phases and management functions is necessary for the sucess of the project. In order to achieve it, the corresponding management activities are shared by ELETRONORTE and consultant companies as described in the next items, which treat the areas of inspection; of coordination of interfaces; and of general planning and control.

7.2 Division of Management Activities - Inspection

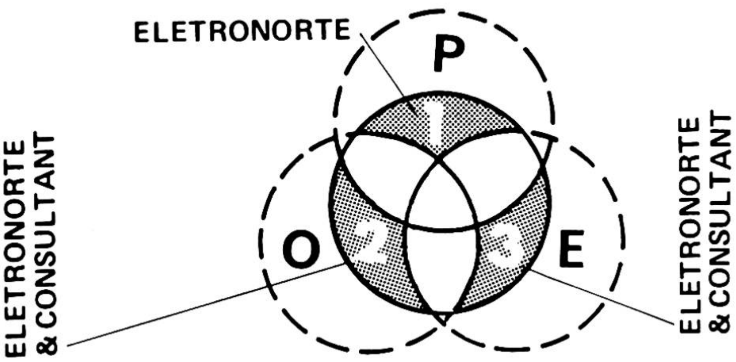


Figure 2

There are three kinds of inspection activities, corresponding to the shaded areas 1, 2 and 3 in figure 2. Shaded area 1 represents project control; shaded area 2 represents supervision of construction and assembly; and shaded area 3 represents inspection of equipment. These activities are shared by ELETRONORTE and the consultant as follows:

7.2.1 Project Control

This activity is done by ELETRONORTE. It includes:

- Quality control of design;
- Faithfulness of executive project to basic design;
- Comparisons between quantities as measured during construction and corresponding forecasts in the executive project;
- Inspection of progress of civil works;
- Approval of changes in the executive project due to conditions which appear during construction.

7.2.2 Supervision of Construction Work and Assembly

This activity is shared by ELETRONORTE and the consultant companies in the following way:

- ELETRONORTE is responsible for:
  . Utilities for construction site (both workshop and residential areas - during the peak of the construction phase there are 28,000 workers, who, with their families, total 55,000 people living in these areas), including their maintenance and community services.
  . Supply of the larger items of materials and equipment.
- The consultant is responsible for:
  . Quality control of civil works and assembly.
  . Supply of small items and of additional personnel when required by ELETRONORTE.

7.2.3 Inspection of Equipment

This is also shared by ELETRONORTE and the consultant, as follows:

- Specifications - ELETRONORTE
- Oversee manufacturing - in Brazil - ELETRONORTE
  - other countries - consultant
- Quality control, testing, quantity control for payments, internal transportation, shipping and storage:
  - in Brazil - ELETRONORTE
  - other countries - consultant
- Transportation which demands special procedures or special vehicles: ELETRONORTE.
- Insurance, customs, taxes - ELETRONORTE
- Technical personnel for tasks which are of ELETRONORTE responsibility, when unavailable at ELETRONORTE - consultant.

7.3 Coordination of Interfaces

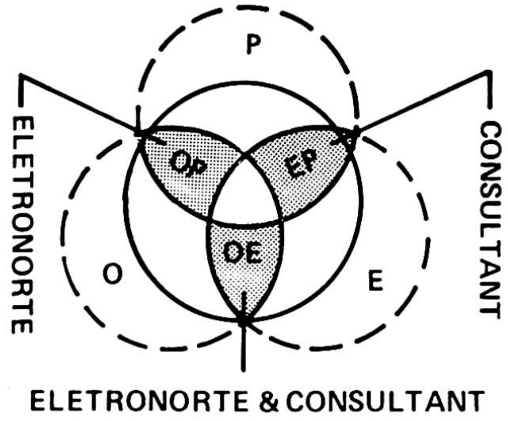


Figure 3

During the execution of a project, the many contacts between the technical staff of the consultant companies and that of ELETRONORTE tend to create a good relationship between the companies, which in turn is useful in solving the problems caused by the interfaces between the various areas.

ELETRONORTE reserves for itself the general coordination of the solutions to these problems, but it usually shares the corresponding management work between its own staff and that of the consultant companies.

In general, the work is divided as shown in figure 3:

OP interface (between design and construction work): ELETRONORTE
EP interface (between design and equipment): consultant
OE interface (between construction and equipment):ELETRONORTE and consultant (mixed group)

These interfaces are very important and complex. The solutions to the problems they pose are usually worked out by the corresponding departments in ELETRONORTE and in the consultant companies, but sometimes they involve decisions which must by taken by the boards of directors of both companies.

Figure 4 shows the mechanism by which decisions are taken. The autonomy of the resident staff must be compatible with the great distances of the Amazon region. Global management problems and their consequences are usually detected first by the resident staff, which takes decisions at its own level and communicates them to the relevant departments of ELETRONORTE and of the consultant companies, thus starting the procedure represented by figure 4, which is used for making any changes that may be needed.

With this mechanism, ELETRONORTE resident headquarters has local executive power for matters related to the execution of the project, with a direct link to the corresponding departments. Thus, it can contact the project area of ELETRONORTE in anything that relates to the actual execution of the project, specially when local conditions force changes of design. In the same way, it can contact other areas for solving management problems as they appear.

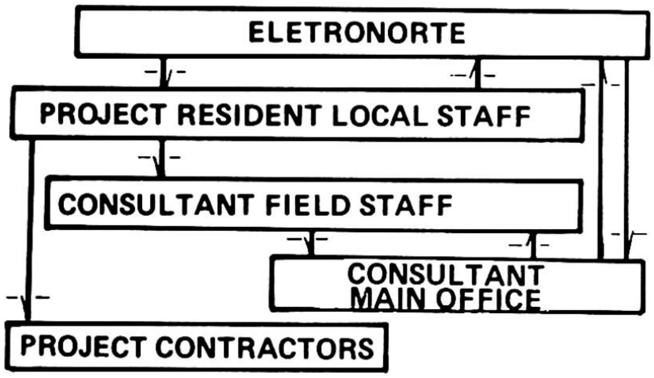


Figure 4

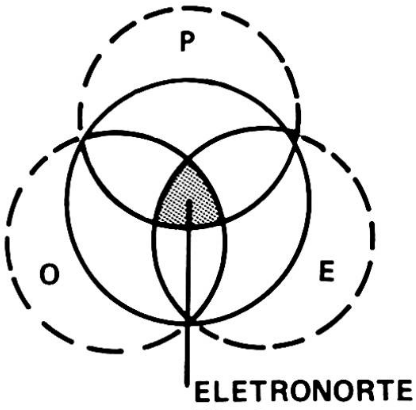


Figure 5

7.4 General Project Planning and Control

ELETRONORTE, as a subsidiary of ELETROBRÁS, must follow the objectives determined by the central planning of its holding company. Subject to this condition, the planning and general control of the Tucuruí project is done internally by ELETRONORTE (Figure 5). Within the objectives which are programmed and specific instructions which are issued by ELETROBRÁS, specially those concerning financial matters, ELETRONORTE establishes its own annual objectives for the project. It then gives to the resident staff the task of preparing detailed objectives for the year, for both the consultant companies and the contractors. Thus, a qualitative and quantitative program is established and the corresponding tasks are given to the consultant companies, so that they can program their own personnel and other requirements for the year.

7.5 The Management Staff

The management of the execution of the Tucuruí project, whose main aspects have been summarized, involves 610 people, of which 34 are employees of ELETRONORTE and 576 of the private companies, whose activities are:

ACTIVITY	UNIVERSITY DEGREE WITH	UNIVERSITY DEGREE WITHOUT	TOTAL
Command of Field Staff	1	4	5
Concrete Quality Control	14	121	135
Earth and Rock Moving	12	134	146
Electromechanical	12	27	39
Complementary Activities	22	166	188
Administrative Activities	1	22	23
SUBTOTAL	62	474	536
Staff Support - Brasília	5	19	24
Staff Support - São Paulo	9	7	16
Complementary Activities	-	-	-
TOTAL	76	500	576

For the Tucuruí transmission system management,during the construction of its 1,200 km, 500 kV/230 kV lines, ELETRONORTE had, at most, 25 employees directly assigned to it, while at same time a total of 5,600 persons were involved with the project.

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2) Prof. Ladi Biezus, in separata of São Paulo's State Department of Water and Sewers Review number 119/1978, "The SANEGRAN's Implementation".
3) Consortium THEMAG/ENGEVIX reports and publications.

Project Management for the Chongqing Yangtze River Bridge

Gestion de projet pour le pont Chongqing sur le fleuve Yangtzé

Projektmanagement der Chongqing Yangtze Brücke

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Zuoling Liu, born 1915, received his degree at National Zhejiang University, Hangzhou, China, in 1937. For more than 40 years he was engaged in bridge design and construction works in China. He was responsible for the design of Liuzhou bridge Guangxi, China, and the Chongqing Yangtze River bridge.

SUMMARY
The procedures and systems in engineering and construction management, in general, for major projects in China is described in this paper. Now, as economic reforms are being carried out in China, there are prospects for a change in the management of bridge projects. The Chongqing Yangtze River bridge which is a well-known prestressed concrete T-framed bridge in China, is taken as a practical example.

RESUME
Le système général de la gestion des grands projets de construction en Chine est décrit dans cet article. La Chine révise actuellement son système économique, ce qui ouvre la perspective d'une réforme de la gestion des ouvrages d'art. Le pont de Chongqing sur le Yangtzé, un pont célèbre en béton précontraint, dont la structure principale est un cadre rigide, est présenté comme exemple.

ZUSAMMENFASSUNG
In diesem Artikel werden Verfahren und System auf dem Gebiet des Engineering und Construction Managements dargestellt, die in China im allgemeinen bei grossen Bauprojekten zur Anwendung gelangen. Zur Zeit wird eine Reform des Wirtschaftssystems in China durchgeführt, die auch Aussichten hat, eine Änderung des Projektmanagements für Brückenbauten zu bewirken. Die Chongqing Yangtze Brücke, eine in China bekannte vorgespannte Betonbrücke mit dem T-Rahmen, wird als Beispiel verwendet.

1. GENERAL ASPECTS

The Chongqing Yangtze River bridge, with a total length of 1120 meters, is an eight span T-framed prestressed concrete bridge, made up of a number of cantilever T-frames plus suspended spans of 35 meters each. The main span is 174 meters, which is at present the greatest span of its type in China. The bridge is located at the central district of the city of Chongqing, Sichuan province, China. It serves to connect the urban district of the two shores and joins the inter-state highways. The bridge was opened to traffic on July 1, 1980.

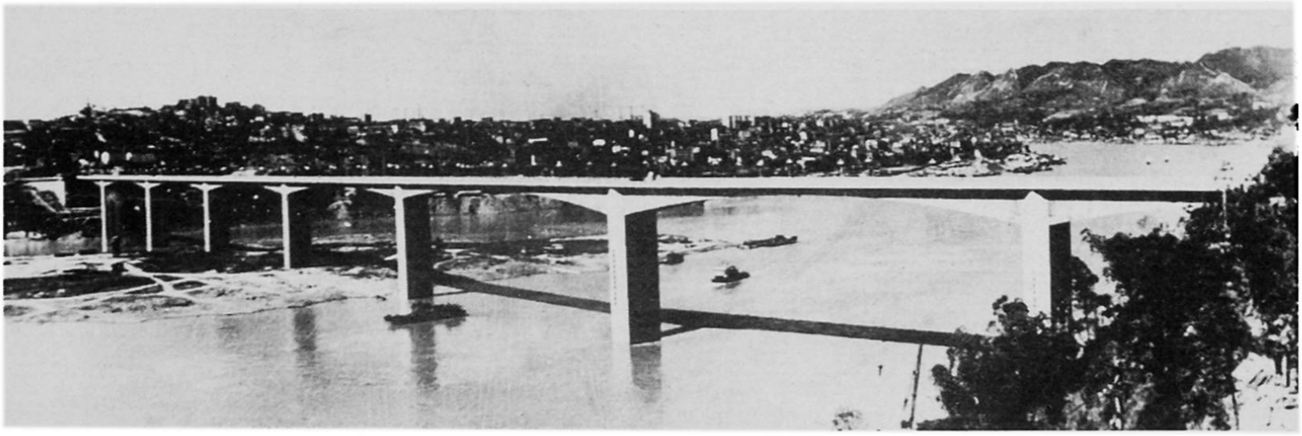


Photo 1 General View of The Chongqing Yangtze River Bridge

Photo 1 is the whole of the bridge completed, the spans are composed of: 86.5m + 4 x 138m + 156m + 174m + 104.5m. The bridge width is 21m (See Fig. 1). The bridge piers are made of reinforced concrete cellular structures, whose height averages 64m from the top of the footing to the top of the bridge deck. The pier shafts are of equal sections to conform slip-form construction. Different kinds of foundations were designed according to the geological conditions at each pier site. Three types of foundations were adopted, namely: the open cut spread footings, reinforced concrete open caissons, the floating steel open caisson with cast-in-place concrete piles.

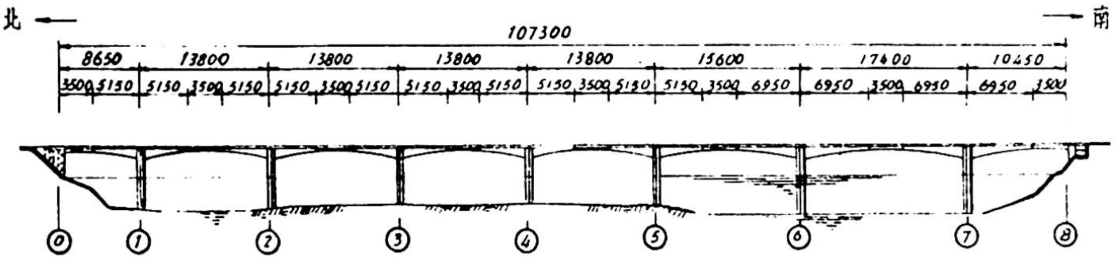


图 1 全桥孔径布置图
Fig. 1 Elevation

Fig. 1 Elevation

Pier No. 6 is a deep water pier, which was a critical part in construction of the whole bridge, and was a controlling factor to the period of construction. Fig. 2 is a sketch of the pier structure, including its foundation. Double-walled steel caisson was used. Outer diameter of caisson is 23.4m; total height of caisson is 17.5 - 19.5m. The knife edge of the caisson was made high and low to fit the contours of the rock surface. The caisson was fabricated in floating position and was sunk by partly pouring concrete between walls and partly by pumping water in.

12 cast-in-place piles of 2.6m diameter each, were arranged within the caisson, and were encased in a solid concrete cap of 6.5m thick.

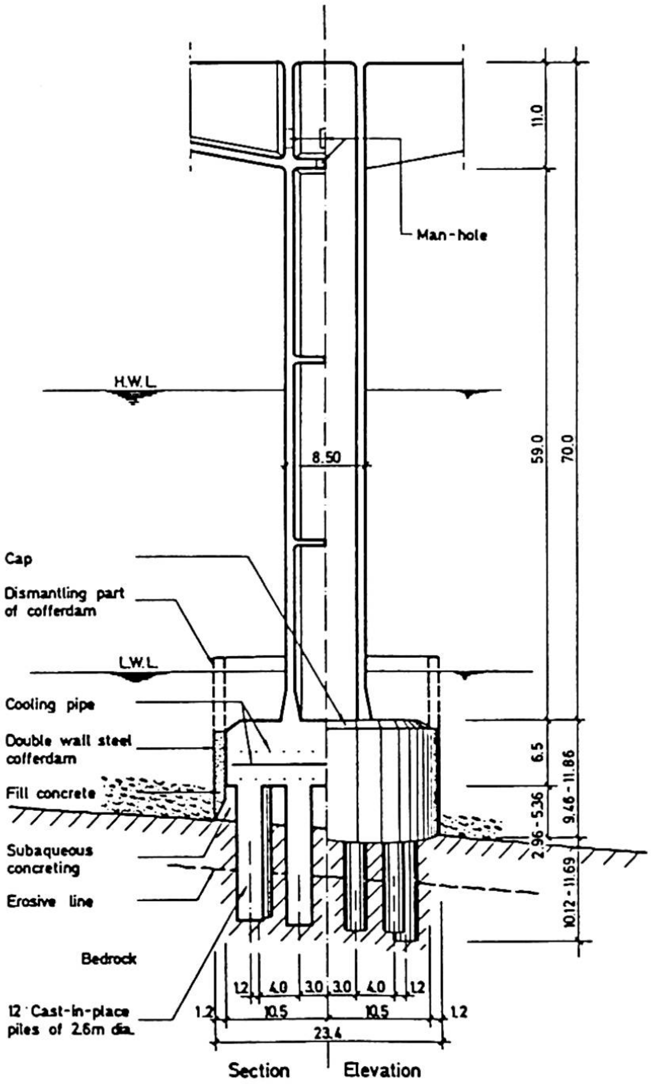


Fig.2 No 6 Pier

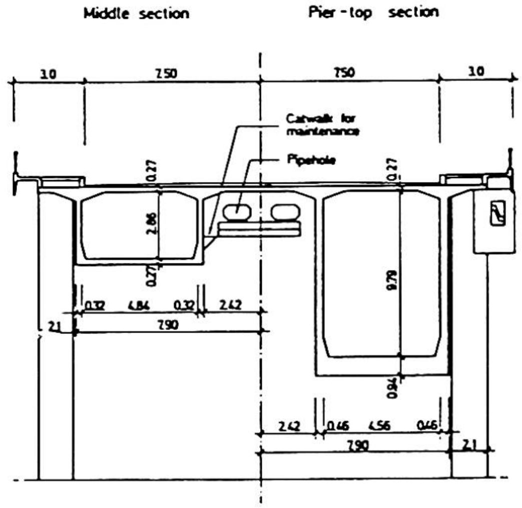


Fig.3 Cross section

In the superstructures, cast-in-place balanced cantilever segmental construction method by means of travelling carriages was used. The cross-section of the cantilever arms is shown in Fig. 3. For the 174m span, the cantilever arm was divided into 20 segments, with the lengths of each segment varying from 2.5 - 4.0m. The weight of each segment was equal around 100t. The box girders were prestressed in three directions. The longitudinal and transverse prestressing tendons were made of 24-5§high tensile steel wires for each strand. 28§ high tensile steel bars were used for the vertical prestressing in the webs.

2. DETERMINATION OF THE PLANNING PROPOSAL

Early in 1966, the local government had studied the problem of building a bridge in Chongqing over The Yangtze River. Along the 9.4 kilometers of river shore in the urban district, four bridge sites were sifted out for comparison against ten localities which had already undergone preliminary studies. The bases of comparison are: the city's master plan of municipal construction and present status, geological conditions of the two banks, the navigation conditions of the river section, economic benefit, traffic and transportation requirements, and construction costs, etc. Simultaneously, a preliminary consideration was made for the schemes of bridge types against the recommended bridge sites, and at the same time the amount of investment was estimated.

Actually, the work of this period corresponds to the investment orientated research. If the work done was comparatively thorough, then it will be something like a feasibility study.

According to the result of these studies, the client unit (mostly the competent authority of the local government) immediately compiled the plan of proposal of the bridge project. At the end of 1975 it was approved by the higher level authority. So far, the item of construction was already defined.

Municipal public work projects are mostly non-profit enterprises, their benefits are a kind of social benefit. Proposals for projects were frequently a result of the existing traffic requirements or other urgent needs of the public. In China, up to now, the bridge is free to pass. Recently, a few districts also considered building toll bridges and welcoming private investments. However, this ideas are not implemented yet.

The client unit can usually entrust comparatively large bridge projects to a few designing institutes or universities, and research institutes, asking them to provide some preliminary conceptional schems according to the client's intention. Then these are analyzed, studied, compared by the chosen designing institute together with the client unit.

3. DESIGN

After the approval of the project the design stage is started. The design work does not call for bids, but is assigned to the design unit as a mission by a high level authority or the client unit enters directly into contract with a chosen design unit.

The Chongqing Municipal Construction Bureau confered the design of the Chongqing bridge to the Shanghai Municipal Engineering Design Institute.

Preliminary design consists mainly of the following contents: Estimation of traffic volume after the completion of the bridge; analysis of the bridge's economic benefit; determination of technical criterion of the bridge; hydrological calculations and bridge site design; general planning and the comparative analysis of different alternatives of bridge types; estimation of engineering quantities and amount of materials; special requirements and equipments during construction; construction schedule; total cost of investment etc.

The bridge type alternatives had been extensively investigated in the first stage of the bridge design. Members of the design institute and technical personnels of other units put forward a total of 17 alternatives. Through joint analysis and discussion by the client unit, the constructing unit and the design unit, those which were not suitable to the specific conditions and those which were not mature in design and construction techniques, were eliminated. Finally, six alternatives were condensated by the design group.

a. Double cantilevered frame (πframe) plus suspended span with a main span of 240m.

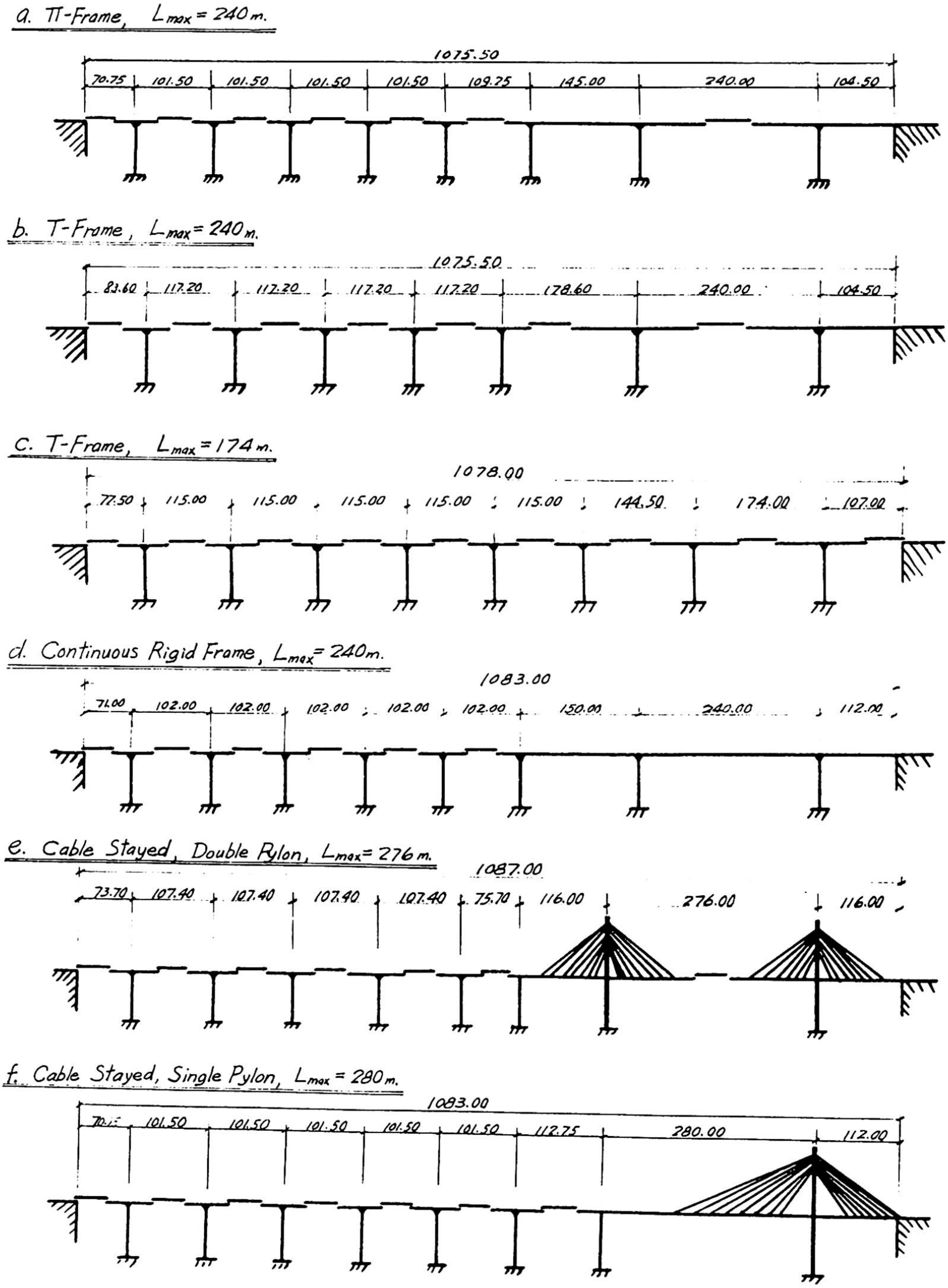
b. T-framed structure plus suspended span with a main span of 240m.

c. T-framed structure plus suspended span with a main span of 174m.

d. Three span continuous rigid frame with a main span of 240m.

e. Double pylon cable stayed bridge with a main span of 276m.

f. Single pylon cable stayed bridge with a main span of 280m.



Schematic Diagram of Alternatives

Fig. 4

Through conferences and preliminary selection (including the possible construction unit), the above mentioned alternatives a, c, e were considered to be comperatively advantageous and further analysis and comparison had to be made.

For the analytic comparison of factors concerning material consumption, functions in use, navigation influence, cost, time limit for the completion of the project, construction risk, aesthetic appearance, and maintenance etc. of the three alternatives, a T-framed structure with a main span of 174m was finally recommended.

During the preliminary design, the design unit and the probable construction unit kept in close contact regarding the construction problems and exchanged views continuously. But these construction schemes initially considered were often subjected to possible changes due to the alteration of construction unit and changes in conditions. This fact made the design work more laborious. In China, the construction units have comparatively more influence than in other countries.

The selection of standard criteria should be made in the preliminary design. The design of this bridge is mainly based on the Chinese highway bridge design specifications, and refers to Chinese railway bridge design specifications.

For a few exceptional problems, it is necessary to get the information from tests. For instance, the pier locations in the deep water navigation channel were determined through experiments. Utilizing a few representative ship fleets and rafts to pass through the bridge site (the pier marks were set up in advance), measured their navigating track and then made comparisons.

The test and the research expenses of the preliminary design stage were decided by the client unit.

The preliminary design was finally appraized by large scale meeting chaired by a superior authority member. The meeting gathered engineers of some 50 units of bridge design and construction, traffic and transportation, engineering geology, scientific research, universities and colleges for discussion and appraisal in Chongqing.

Finally, at the end of 1976, the preliminary design was approved, and the construction of the 174m T-frame scheme was resolved.

4. PROJECT ORGANIZATION FOR THE REALIZATION PHASES

For the Chongqing Yangtze River Bridge, the local government demanded "Quality first, and complete within 3 years". According to this demand, in view of the size of the project, construction conditions, ability of construction units, the client department decided to assign the job to several contractors under a single command unit.

Therefore, the Chongqing Yangtze River Bridge Headquarter was established as the directing organization. Its main tasks were: to organize surveying and geological reconnaisance as well as design and construction, the allocation of principal materials and facilities, transportation of materials, land acquisition, dismantling of residential buildings, catering of daily necessities etc. Its duties also included: general development of construction sites, planning of a unified general scheme of construction, drafts for the construction methods, determination and control of the quality standard for the whole bridge according to the design requirements; reasonable allocation of the construction funds etc.

All the contractors also established their own directing offices, whose tasks were: to organize the construction essentially according to the planning, technical standards, and construction schemes prepared by the headquarters; to be accountable for the construction quality of the engineering elements, the time schedule, and the safety of the workers; to control the budget and to take responsibility for the profits or losses of the respective contractor.

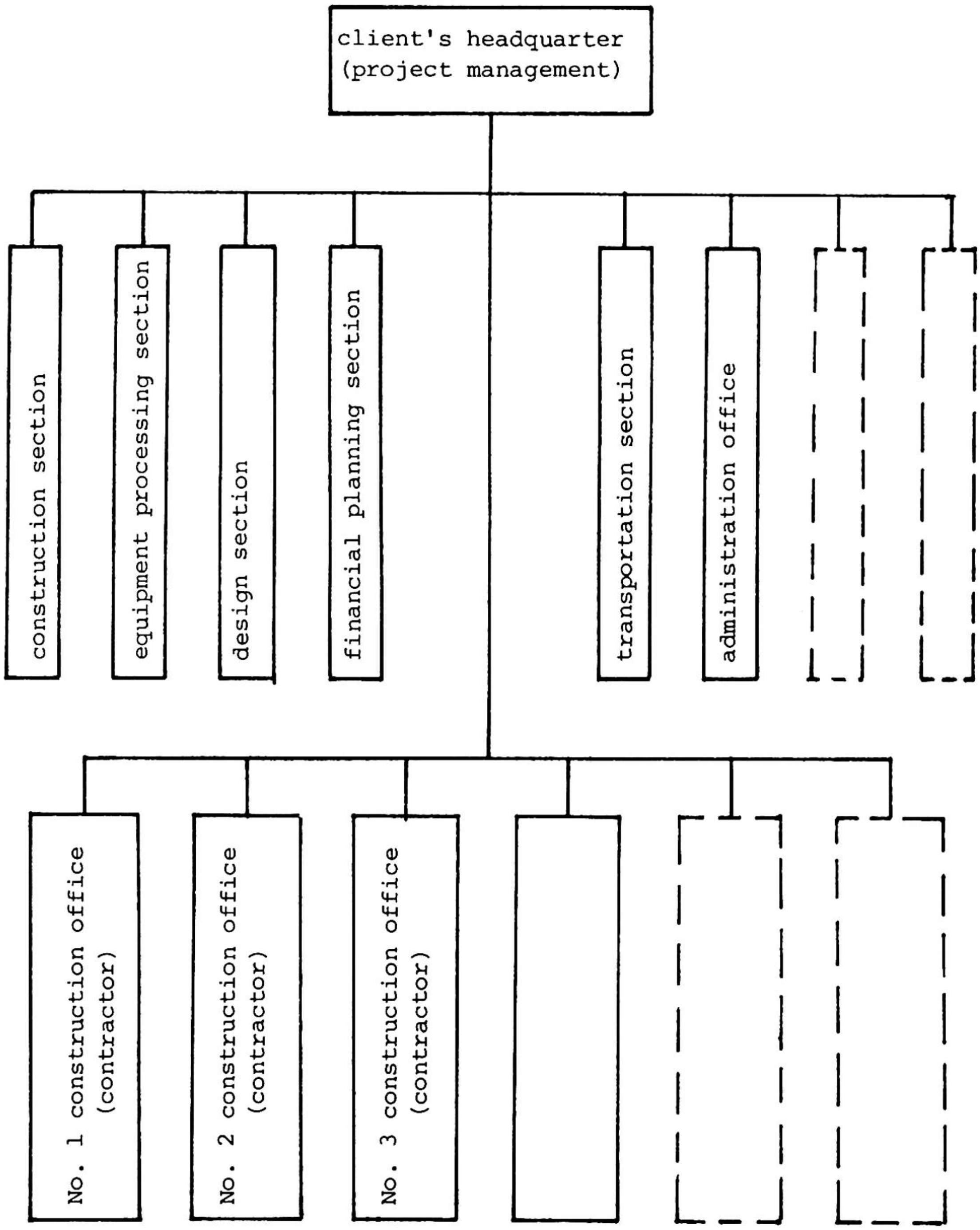


Fig 4: Construction organization chart

As a result of practice, this kind of organization fit to the actual condition at that time. Good results were obtained efficiently due to clear assignments, obvious objectives, democratic decision methods, and coordinated actions of all the organization units.

The main job assigments to contractors were:

First contractor:	Entire Pier No. 1 (including foundation) and T-frame, Prefabrication and erection of suspended spans for the whole bridge, North abutment and approach.
Second contractor:	Foundation of Pier No. 2.
Third contractor:	Pier shaft of pier No. 2 and T-frame, entire pier No. 3 and T-frame,
The forth contractor:	Entire pier No. 4&5 and T-frame,
The fifth contractor:	Entire pier No. 6, 8, 7 and T-frame, South abutment, bridge head tunnel, bridge deck pavement, pedestrian walk etc.
The sixth contractor:	South approach etc.

In People's Republic of China, a construction unit is usually selected by negotiating a contract or by appointment by the higher level authority. Recently, the Ministry of Municipal and Rural Construction resolved that: Hereafter, ordinary engineering projects should use the bidding method to determine the construction unit. As to the design unit, priority should also be given to the most competitive one. Henceforth, this will improve the engineering construction and management.

5. CONSTRUCTION MANAGEMENT

5.1 Time scheduling

In accordance with the anticipated completion time for the whole project, the time schedule of the construction of the bridge itself was divided into 4 stages.

5.1.1 Construction preparatory stage

The scheduled time period for this stage was from March to Oct. 1977. The principal works done in this stage were to pave the way for a predetermined date of commencement of construction work. The following works are included: establishment of a directing office; organization of technical reconnaissance of the project and arrangement of the design of work drawings; drafting of time schedule; study of construction methods & procedure; organizing design for specific construction methods; conducting of necessary research work; supply of resources; planning of construction site; carryout of three installations & one leveling (installation of water mains, of electrice wire cable, of roads and leveling of site ground); establishment of administrative rules; preparing workers to move-in; etc.

The preparatory works are very important. A special schedule for preparatory works was made. The scheduled works were reviewed each week and internal or external disturbances were studied and corresponding measures taken, so as to ensure that the works are completed as planned.

The overall construction programme and the choice of construction methods & procedures were all taking their shape in this stage.

5.1.2 Foundation and pier construction stage

The scheduled time period for this stage was the first low water season of Yangtze River in this year, i.e. from Nov. 1977 to May 1978. The requirements for the progress of different items of construction were defined, according to conditions & methods of construction. They were: foundations of piers No. 1 to No. 5 & No. 7 to be completed; pier shaft No. 1, 3, 5, 7 to be completed; at least three piles & sub-aqueous sealing concrete to be finished for pier No. 6, ready to stand against the flood. It should be noted that pier No. 6 was the critical part of construction to the whole job, a controlling factor to the time schedule.

Slide-form was used for pier shaft construction. Many kinds of labor work were involved in the determination of jacking period. So the principles of operations research network planning were used to choose a proper jacking period.

5.1.3 T-frame construction stage

Before June 10th,1978 all pier shafts except pier No.6 and pier No.7 were entirely completed in advance. From June to October, it is the flood season of Yangtze River, the construction site was often subjected to the flooding threats. During this period, the creation and exchange of the construction team and another part of preparatory works were arranged originally while the construction of the critical pier No. 6 would continue during the flooding period using cableway transportation. According to the latest situation (ahead of time in most works) and from reviewing the work of previous stage, it seemd adequate that the flooding period should be more suitably used. So the construction of box girder sections on the pier went underway intermittently. Using this strategy, a period of about two months was saved.

The continuous construction of T-frame No. 6 during the flooding period progressed smoothly, it was completed ahead of time, before the end of December. Up to now, the T-frame of pier No. 6 which controlled the general schedule of the whole bridge had already been completed six months in advance.

5.1.4 Bridge deck construction stage

The construction works of this stage were: the erection of suspended spans and bridge deck pouring, casting of pavement on the whole bridge decking, installation of the pedestrian walks, railing, lighting etc. and other finishes works. From August 1979, the erection of suspended spans started and up to the middle of Feb. 1980 the entire suspended spans were completed. The erection work had to be interrupted for three months, waiting for the completion of T-frame No. 6.

Hereafter, on the 17th of June, the loading test of the bridge started. Static and dynamic loading tests were made to obtain the stresses, deformations and deflections of the principal parts of the bridge. The bridge was opened to traffic on July the 1st.

5.2 Updating of the construction Systems

Whenever there were disturbances to the planned execution, or when construction works were ahead of time, then the work scheme was adjusted through negotiation. For instance, pier No. 6 was the key portion of the project regarding the time of completion. The original plan was to finish the subaqueous sealing and three cast-in-place piles before the flood, while construction during the flooding period would have been stopped. But after the job started, all kinds of work proceeded successfully. This was due to the delibration of preparatory works, serious construction work and suitable construction procedures. After the subaqueous sealing had been finished, an analysis of the hydrological datas, conditions for construction and time factors led to the conclusion of striving to finish all the piles, provided certain measures could be taken. Then the schedule of the whole bridge could be pushed ahead of the planned times.

Thereby the height of steel cofferdam was resolved to increase, in order to suit to a higher construction water level, and adopting a series of other flood combating measures. Finally the entire foundation piles were completed at the beginning of June.

5.3 Measures of assuring quality and scheduled time

For assuring the engineering quality, the construction headquarters formulated: The stipulations of technical responsibility of Chongqing Yangtze River Bridge; inspection standards of engineering quality of the Chongqing Yangtze River Bridge; regulations of investigating the engineering quality of Chongqing Yangtze River Bridge etc. All contractors were asked for following these policies strictly. The construction headquarter had its quality supervisors, all subcontractors had their own quality inspectors, too. They all investigated every working procedure uninterruptedly during the entire detailed engineering and construction process. The engineers of the headquarters kept themselves well informed about the engineering quality of all sections of construction.

For some new techniques in construction, which were unfamiliar to the subcontractors tests in operation were requested to get experience and to ensure engineering quali

All contractors were responsible for the time schedule of their own work. On each specified period the client's project management called for a meeting to study whether some part was behind schedule or having the possibility of lagging behind. Then measures had to be taken for remedy and the program of the next stage was updated in order to guarantee the overall time schedule. Besides, prompt supply of materials and equipment had to be kept in mind, as well. The supply of materials and equipments of this bridge were all in the hands of the respective departments of the Chongqing municipality and personnel was transfered to work in the headquarters for the convenience of contacting and solving problems.

The work drawing design was furnished by the design department on time, no losses of time in supplying work drawings had occurred in the construction of this bridge. Moreover, a small residential group of designers was assigned to the bridge site to be responsible for solving problems raised by the construction unit and drew some supplementary drawings due to the changes of conditions on the bridge site.

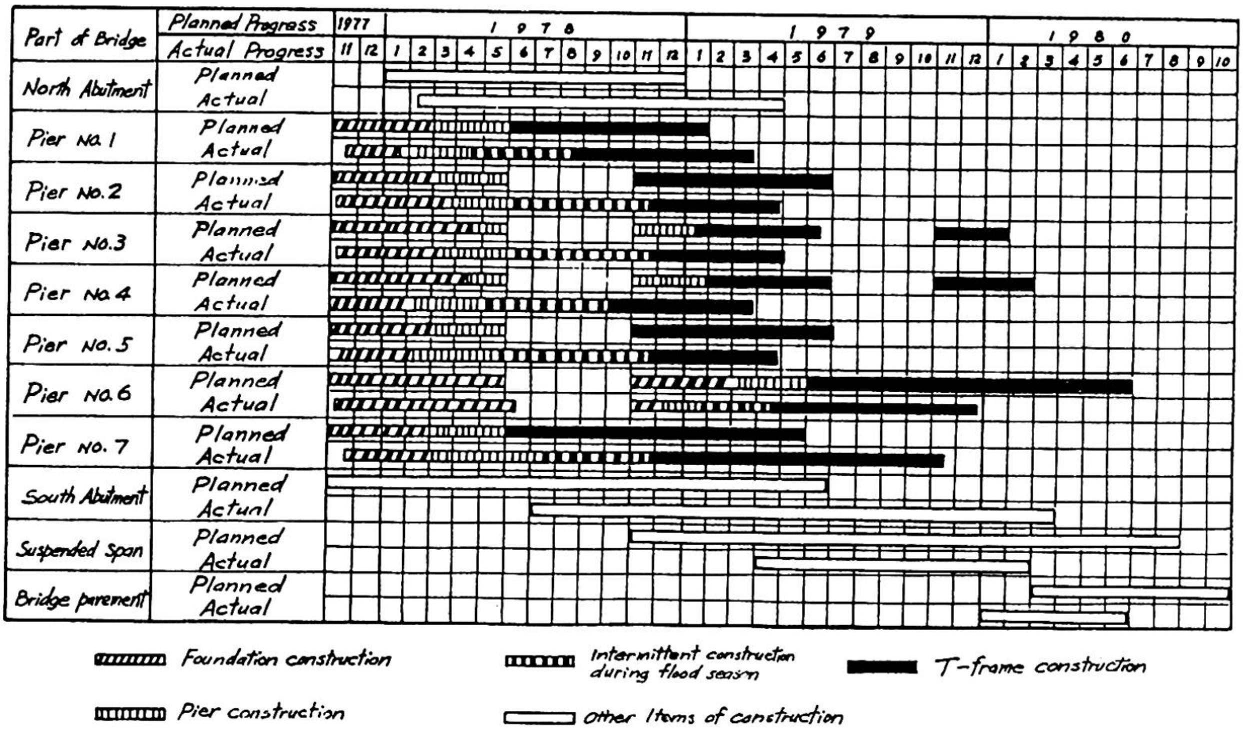
6. CONCLUSION

As to the real assurance of quality and time schedule of engineering construction, attention should be paid to the preparation of construction works and technical reservations. All preparatory works must be made well conscientiously. Furthermore, every phase of construction methods & procedures should be studied seriously to conform with the actual conditions on site. To guarantee the quality and time schedule of a project, this is a kind of vigorous and active measure.

Simultaneously, the innovation of construction program or construction technique should be encouraged, and rationalization proposals should be awarded to enhance quality and to speed up the schedule.

Setting up an on-the-spot design group on site by the design department is a desirable way of enhabling better cooperation between design and construction.

Adopting of test constructions in a limited scale for unfamiliar technologies is also desirable. This small amount of expenses should be allowed within the general investment cost.



Planned Work Schedule Vs. Actual Progress
Chongqing Yangtze River Bridge

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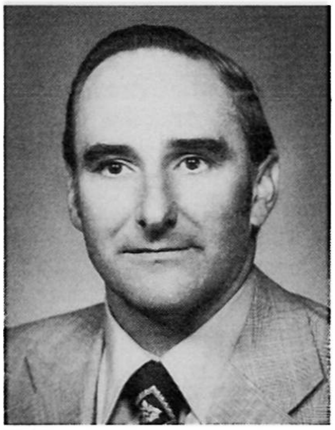
Advanced Light Rapid Transit (ALRT) System, Vancouver, BC

Système de transport en commun en site propre, Vancouver, BC

Öffentliches Verkehrssystem auf Eigentrasse, Vancouver, BC

Terence M. WARDLE
Vice President
Acres Consult. Services
Vancouver, BC, Canada



After qualifying as a structural engineer in the United Kingdom in 1952 Terence M. Wardle came to Canada and participated in bridge design with a major railroad, consultant and the BC Highways Ministry. In the sixties he spent six years on structural research in New Zealand and the U.K. Mr. Wardle joined Acres in 1969 and is now responsible for the direction of a broad range of transportation, energy and industrial sector prospects in the Pacific region.

RESUME
The paper describes the 21 km system and the project management approach to the project. The organization of the project group is discussed and the management strategies which are being utilized to meet the budget and schedule constraint. The project approval was given in mid '81 and completion was required by January 86 in time for the Expo 86 World Fair. A prebuild section was constructed to demonstrate the design and operation in 1983. The system utilizes linear motor, driverless trains and the cars have steerable trucks making the system unique.

RESUME
L'article décrit le système de transport en commun de 21 km de longueur et sa réalisation, à l'aide de la gestion de projet. L'organisation du groupe d'études est présentée ainsi que les techniques de gestion de projet appliquées pour respecter les délais et budgets. L'approbation du projet date du milieu de 1981 et sa réalisation doit être terminée en janvier 1986 pour l'ouverture d'Expo 86. Un tronçon d'essai a été construit en 1983, afin d'évaluer la structure et l'exploitation. Le système fait appel entre autres, au moteur linéaire et à la conduite automatique des trains.

ZUSAMMENFASSUNG
Der Artikel beschreibt das 21 km lange Verkehrssystem und dessen Ausführung durch die Projektleitung. Die Organisation der Projekt-Gruppe und die angewandte Strategie zur Erfüllung der Randbedingungen, gesetzt durch das Budget und den Zeitplan, werden erläutert. Die Genehmigung des Projekts wurde Mitte 1981 erteilt und die Vollendung auf Januar 1986 gefordert, rechtzeitig für die Weltausstellung Expo 86. Ein vorgefertigtes Segment wurde 1983 gebaut, um die Gestaltung und die Funktionsweise zu zeigen. Das System bedient sich eines Linearmotors, führerloser Züge, und die Wagen haben lenkbare Drehgestelle, welche das System einzigartig machen.

1. INTRODUCTION

In May of 1981 the Hon. W. Bennett Premier of British Columbia announced the commitment to a rail transit system in the Lower Mainland. The system chosen was to be high technology. The first 21.4 km leg of the system was to be in full operation prior to the opening of EXPO '86. A clear objective was established to create a highly cost effective system within the schedule required to meet the exhibition opening.

B.C. Transit (BCT) was given the responsibility of creating the system and bringing it to full operation. A system master contract was awarded by BCT to the Urban Transportation Development Corporation, an Ontario Crown Corporation, and it's subsidiary Metro Canada Ltd. (MCL) for the design, supply installation and commissioning of an advanced light rail system. At the time, BCT did not have a project team in place nor was there a previous project to serve as an example. The challenge was to create the management infrastructure with which to direct and control the project. This paper describes this challenge and how it has been met.

2. THE ALRT PROJECT

The ALRT line runs from the Burrard Inlet waterfront in downtown Vancouver to downtown New Westminister. The line is 21.4 km in length, of which 14 km are on elevated guideway structure 6 km at grade and 1.5 km in tunnel. There are fifteen stations, two underground, eight elevated and five at grade. The vehicle control centre and maintenance complex is 20 acres in extent. Plate I shows the route of the line.

The initial capacity of the system is 10,000 passengers/hour with a maximum future capacity of 30,000 passengers/hour. The total trip time is thirty minutes. The minimum headway between trains is 1 3/4 minutes. The cars have a seating capacity of 40 and total capacity of 75 people. Trains will consist of four cars in peak periods and two cars in the off peak late evenings. Each car is driven by two linear induction motors reacting with a continuous plate between the rails. Power is supplied at 600 volts DC from side rails and is converted on board to variable voltage and variable frequency three phase AC. A unique feature of the vehicle is the steerable axle truck which is designed to reduce noise and improve ride quality.

The system is driverless. The train control has three computer systems. The system management centre computer, which is under the direction of a control operator, carries out supervisory functions e.g. startup, scheduling, emergency operations and shutdown. The vehicle control centre consists of three linked computers for train movement monitoring and direction. The third system is the vehicle on board computer which activates propulsion, braking, door operation and monitors on board equipment.

The track is standard gauge continuous welded 112 lb. rail. The twin guideways are 28 cm concrete slab in the at-grade sections of the line. The elevated sections consist of precast prestressed box section girders spanning 30 metres. The girders are post tensioned for continuity at alternate piers. The cast in situ piers are tee shaped with post tensioned cross heads. Plate II shows a typical/guideway crossection. The underground section utilized an existing

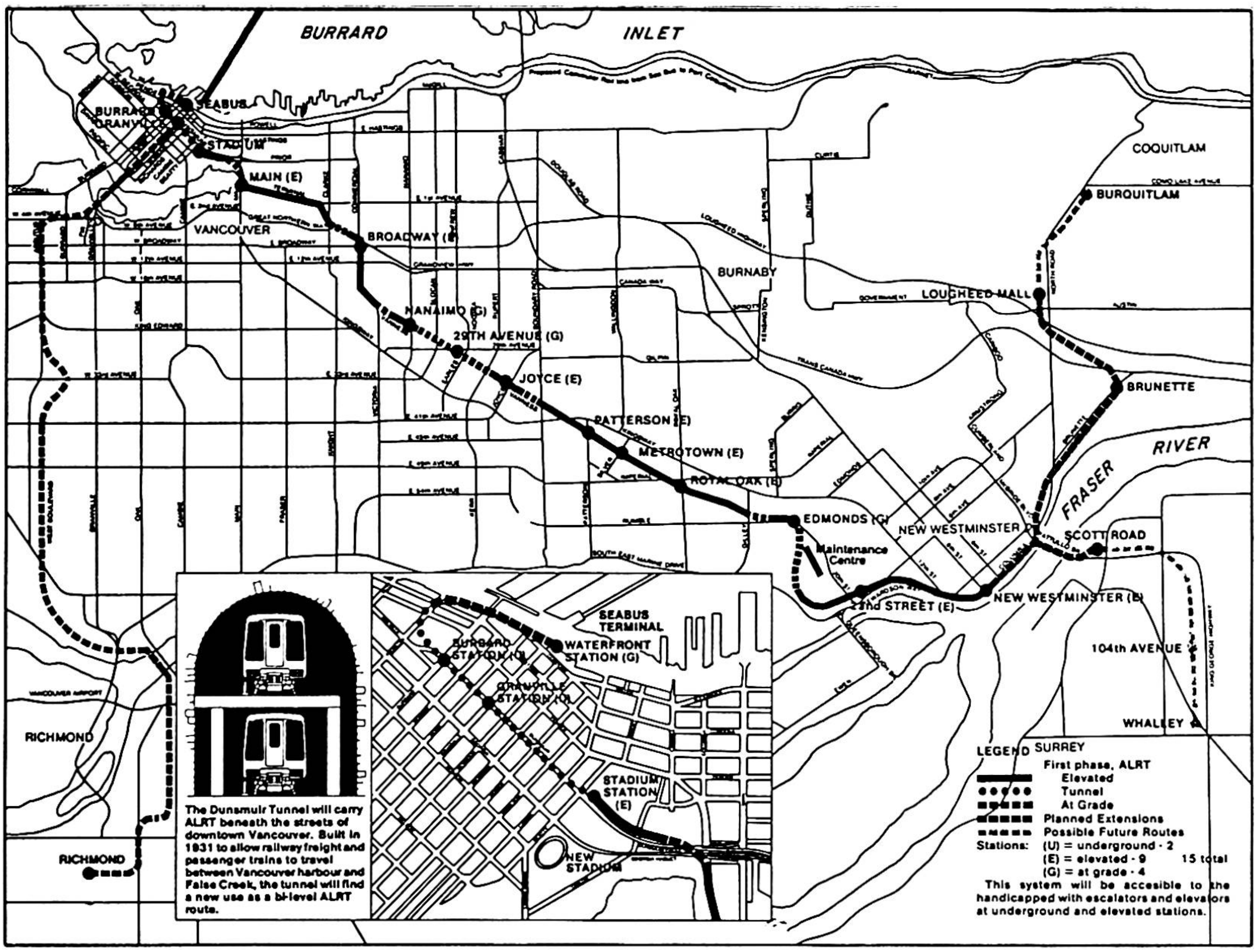


Plate I

ALRT ROUTE

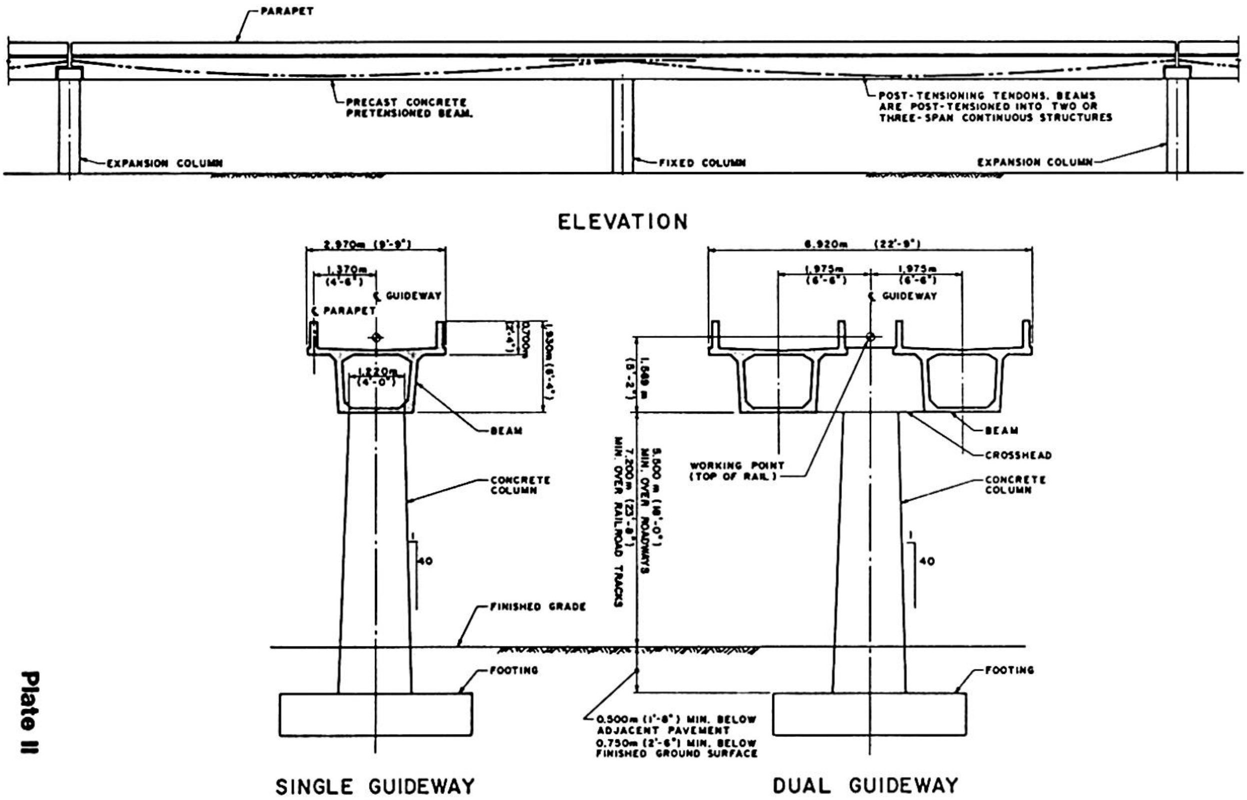


Plate II

TYPICAL ELEVATED GUIDEWAY

railway tunnel. The structure was modified to carry a two level ALRT guideway. Two underground stations are situated on the tunnel section. They were accomplished by widening out the existing tunnel. Plate III shows a tunnel crossection underground station.

The foregoing project description covers Phase I of the system. At the time of writing an extension phase has been authorised to carry the line across the Fraser River into Surrey. The total length of the extension is 7 km. The river crossing will be a cable stayed bridge structure, 450 metres in overall length. Another future extension is planned to Coquitlam. Eventually a second line is proposed from downtown Vancouver to Richmond. However, to date, the Coquitlam and Richmond lines have not been authorized.

3. OWNER'S RESPONSIBILITY

BCT as the owner of the system, has the overall management responsibility for the conduct of the project from initiation of the work to final acceptance of the operating system. The Corporation is accountable to the Provincial government for the control of the project funds. The Hon. Grace McCarthy is the Minister responsible for the project. BCT disburses funds directly in some instances but the main cash flow is disbursed through the system contractor. Budget preparation and requisitioning of funds from the government is the responsibility of BCT.

The Corporation has a direct responsibility under the system master contract to provide a cleared right of way. This entails the acquisition of land by purchase, lease or easement as well as the future disposition of surplus land. The relocation of utilities and crossings of the R.O.W. is also part of BCT's responsibility. The negotiation and legal requirements of the street closings, station approaches, etcetera, is managed by BCT.

The route of the line passes through three municipal jurisdictions and the Greater Vancouver Regional District, which consists of all municipalities in the Lower Mainland. BCT has the responsibility for obtaining consensus with the Municipalities on line location and station locations and other aspects which may impact on their jurisdictions.

Linked to the jurisdictional consensus, BCT has the responsibility for community relations and information at all stages of the project. The communication levels include governments, the business community, and the general public.

Last but not least, BCT has full management responsibility for the direction and administration of the system master contract. This includes agreement of design criteria and equipment specifications, monitoring of design, schedule and cost performance, direct management of construction, and quality assurance, in the construction and commissioning phases.

4. B.C. TRANSIT ORGANIZATION

B.C. Transit is a Crown Corporation which was established by the government of British Columbia in 1977. The general mandate is to provide the public transit

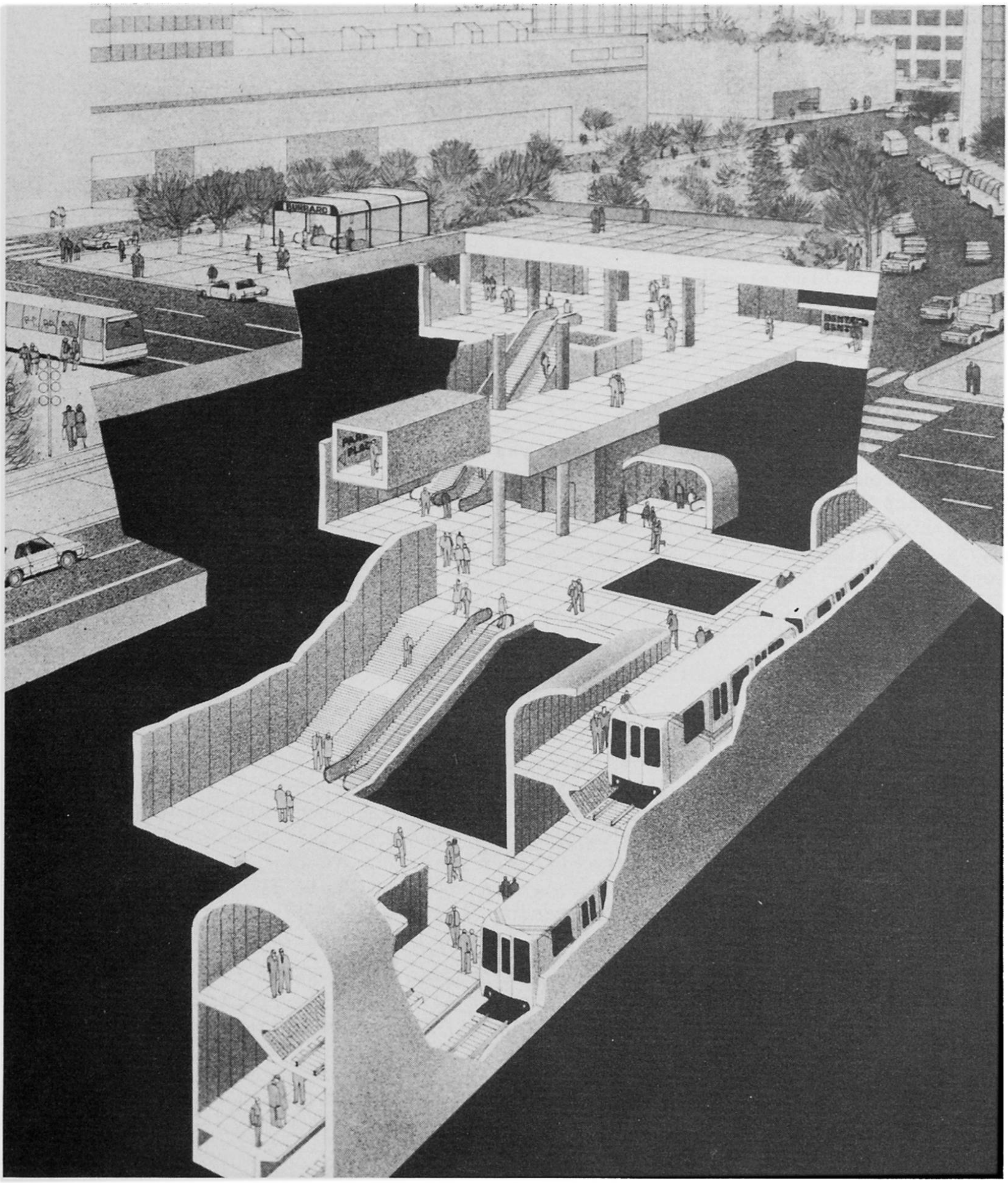


Plate III

UNDERGROUND STATION

services in the Lower Mainland, Victoria, and some smaller communities. The Corporation is governed by a Board of Directors who are appointed by the Government.

The administration of BCT is the responsibility of the General Manager, who is accountable directly to the Board of Directors. Regional Managers look after specific, geographic areas under the overall direction of the General Manager. Each region is responsible for the planning and growth of the transit system within its area.

The Lower Mainland is by far the largest region in terms of transit requirements. Population growth is continuing and the commuter traffic from the new suburban residential areas to the downtown core is expanding. By 1981 it was obvious that the road system was at and beyond capacity. Automobiles, buses and commercial vehicles were competing for ever more scarce road space during morning and evening rush hours. Rail transit systems had been under study for several years. In the spring of that year the government took the decision to implement the system which is now under construction. B.C. Transit was appointed as the executing agency for the project with full responsibility for construction of the line. A Transit '86 committee was established to coordinate the inputs from all levels of government. Under the chairmanship of the Hon. J. Davis MLA, the committee has representatives from all municipal governments along the alignment. The main contract was drawn up between BCT and the system contractor.

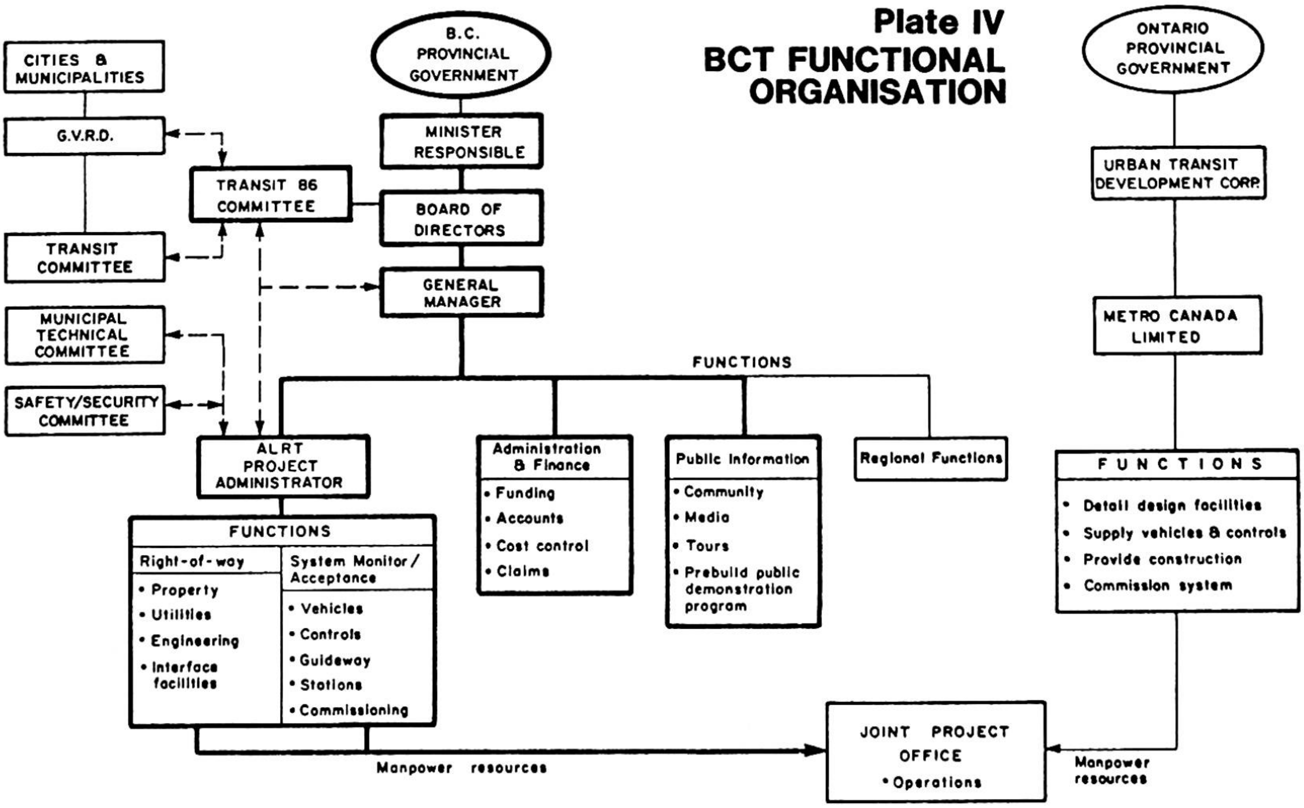
5. BCT PROJECT MANAGEMENT STRUCTURE

At the time that the system master contract was implemented, B.C. Transit did not have a major project management organizational structure in place. The opportunity was taken to tailor make a management structure to fit the project and the owners' specific responsibilities. A project team was established, reporting directly to the General Manager. The management team is headed by a Project Administrator who is responsible for the day to day operations. The management team functional organization is shown on Plate IV. The management structure stems from the basic BCT responsibilities as discussed in Section 3.

The main system contract requires BCT to provide the right-of-way for the system and to arrange for the resolution of all utilities conflicts. The BCT team structure has to include the management of land organization and related legal services and surveys, the engineering and coordination of the utilities removal and related permits. Policy level decisions are developed through the Transit '86 Committee. Working level decisions are facilitated by the Municipal Technical Committee.

Financing for the project is drawn through the BCT Controller based on annual budget forecasts and monthly cash flows. Management of the expenditures is a function of the project team. This stream includes estimating and cost control and scheduling.

The system contract monitoring management activity is a major part of the work load. Included in this stream is the approval of rolling stock specifications and the design criteria for the line and all structures. Detail design reviews were required for all stations, guideway structures and maintenance facilities.



During the construction phase BCT is taking an active role in managing the construction activities. BCT is also directly managing the communications engineering aspects of the project. As a means of managing any technical conflicts which might arise a Technical Review Board (TRB) was established. The five member TRB reports directly to the Project Administrator.

The communications activity functions as the main interface with the business community, and the general public. This includes, public presentations and media coverage and conducted tours for visitors. Also included is the preparation of information brochures and publications. During the demonstration operation period for the pre-build section, public reaction was monitored by this group.

The system contract required that the contractor provide the system detail design, including all civil, structural, mechanical and electrical engineering, and architecture for guideways, tunnel, stations maintenance yard etc. The contractor divided the project into twelve sections and appointed design consultants for each section. One of the section design consultants was also responsible for overall alignment. The system contractor provided overall co-ordination of the detail design. B.C. Transit appointed Acres Consulting Services Limited to provide monitoring and review of the contractors design work as well as the coordination of the right-of-way and utilities clearing and legal surveying. Architectural consultants were retained by B.C. Transit to provide station conceptual designs and overall architectural co-ordination.

For the first two years B.C. Transit and the System Contractor operated individually. Day to day coordination was by means of scheduled and ad hoc progress meetings and written transmittals. The principal interface for design was by submission of drawings and specifications for design reviews. This was achieved on a section by section basis and as for levels of completion 25%, 50%, 95% and 100%.

By mid 1983 major construction was well underway. Communications and coordination between the two groups had become very complex and time consuming. In order to shorten the communication links the two groups were meshed together in a single operating unit called the Joint Project Office (J.P.O.) Staff from BCT, the System Contractor and their respective consulting groups work as a single team. Contractual responsibilities between the parties remain with BCT or the System Contractor as appropriate since the Joint Project Office is not a legal entity in its own right. A specific advantage of this working arrangement is that the owner has a close relationship with the construction process. This facilitates control of budget, schedule and quality of construction.

6. MANAGEMENT STRATEGIES

Each major project has its own particular set of constraints and requirements which require management solutions. This section reviews some of the principal management strategies which have been developed for the ALRT project. For convenience the review is subdivided into the three project management areas, schedule, budget and quality.

6.1 Schedule

The overall schedule is for completion of the line in time for full operation during the Expo 86 worlds fair. The target date set in the main system contract is January 1st, 1986. In addition, a prebuild section was required to be operational during the summer of '83 as a demonstration unit.

The strategy agreed with the system contractor was to subdivide the line into sections. These were then promised to fit into the overall schedule. The centreline and station locations were established by the Contractors principal consultant and agreed by BCT, detail design was then followed up on a fast track basis according to the section priority. BCT land acquisition and utilities relocation was initiated as soon as centreline was known. Station locations tended to be on the critical path since extensive liaison with municipalities was necessary.

6.1.1 Prebuild Priority

The prebuild section was given first priority. It consisted of about 1.0 km of elevated guideway on the edge of the downtown core together with an elevated station. One guideway had to be fully operational, complete with power and controls. A two car train was to be operated and open to the public for the summer of '83. For this purpose a temporary control room and car maintenance facility was required. Apart from the R.O.W. engineering, guideway design review and construction monitoring, BCT had to review and monitor the car design and fabrication, controls and communications for the prebuild.

The prebuild demonstration exhibit was successful and 300,000 people were carried during the five month operation. The prebuild strategy was also very useful in demonstrating the guideway design and erection techniques, as will be discussed in later sections.

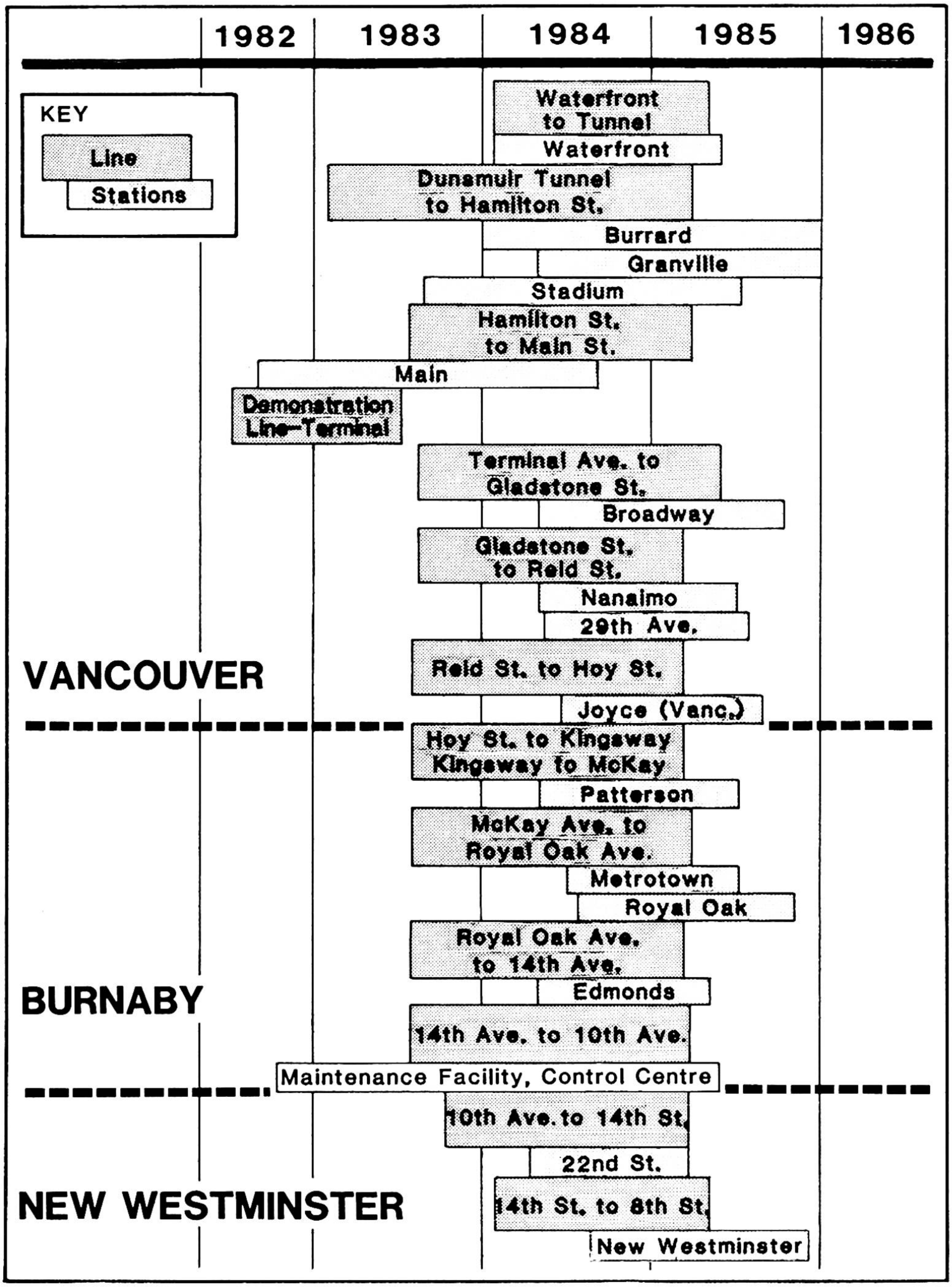


Plate V

CONSTRUCTION SCHEDULE

6.1.2 Tunnel Conversion and Underground Stations Priority

The tunnel conversion and underground stations were extremely high priority items. The tunnel, which was built in 1931, had to be acquired from the railway company and converted to double deck operation. This involved grouting behind the existing lining, rock anchoring and lowering the invert of the tunnel prior to installing the upper guideway. In addition, a short section of tunnel near the eastern portal was relocated for alignment reasons. Since the tunnel is quite shallow in depth and runs close to major buildings throughout its length BCT strategy was to carry out a detailed preconstruction inspection of all structures along the route. Station location was extremely important and full discussions were held with the City and private property owners prior to fixing the locations. Direct access to the stations from major commercial buildings was negotiated by BCT. The Burrard station was sited directly under a city owned park. The Granville station and the east portal relocation required acquisition of privately held land. Tunnel ventilation and fire safety were of particular interest to the city authorities. BCT strategy was to involve the city in the decision making process at three levels, the Transit Committee, the Municipal Engineers Committee and a Safety and Security Committee. With continuing liaison from the earliest days it has been possible to obtain all necessary agreements and concensus without incurring any substantial schedule delay in construction.

6.1.3 Public Impact on Schedule

As has been mentioned previously, BCT established a strong community relations program with a strategy of early and open information on line location alternatives. The overall concept of ALRT in Vancouver met with wide public approval. Naturally, there were specific community concerns to be met in certain areas. Full information was provided in neighbourhood briefing meetings. Wherever possible areas of potential conflict with community needs were ameliorated. In one case a section was relocated from a neighbourhood 'mainstreet' to a backlane. Adjustments in station location were also made. By means of the timely and continuing community relations process, adverse impact on construction schedule has been eliminated.

6.1.4 Schedule Progress

At the time of writing, the construction of the guideway, tunnel, maintenance facilities and fabrication of the rolling stock and equipment is on schedule. There is every confidence that the end dates will be met. Guideway erection will be complete by December, 1984, station construction by September, 1985 and the line will be fully commissioned by January 1st, 1986. The last of the cars will be delivered by mid February, 1986. Plate V show an outline schedule.

6.2 Budget Strategies

When the project commenced in 1981 the economy was booming and inflation was high. In 1982 the economy went into a sharp decline, from which it has not yet recovered. The B.C. provincial revenue is largely derived from natural resources, forest products and mining. With these revenues at below normal levels a policy of restraint in expenditure has been necessary. At the same time, unemployment has been high, particularly in the construction industry, so that the job creation opportunities offered by the ALRT project are important in assisting economic recovery. The overall budget strategy for BCT is to make the most cost effective use possible of the project funds, while providing the maximum opportunities for job creation in B.C. The project budget approved to date is summarized in the table below:

Table I - Cost Summary

I	Vehicles, Track, Train Control	$ x1000	
	Vehicles	$129.7	
	Track & Equipment	104.9	
	Subtotal I		$ 234.6
II	Construction		
	Guideway	196.9	
	Stations	66.1	
	System wide	89.0	
	Subtotal II		$ 352.0
III	Design/Engineering/Administration Property and ROW		$ 238.2
	Subtotal I, II, III,		$824.8
	Contingency		$ 39.6
	Total		$864.4
	Less Special Property Revenues		(10.0)
	Net Total		$854.4

6.2.1 Purchasing Policy

The policy for purchasing construction and equipment is to solicit prequalifications by public advertisement. Bids are involved from prequalified contractors and the lowest bid selected. Justification is required if other than the lowest bid is accepted. Job creation in B.C. and elsewhere is monitored monthly. The breakdown of the job creation distribution up to the end of the first quarter of 1984 is given in the table below:

Table II - Job Creation Distribution

	B.C. %	Other Canadian %	Foreign %
Equipment and Materials	13.2	51.8	35.0
Engineering and Architecture	85.0	4.2	10.8
Construction Contracts	92.8	6.9	0.3
Overall Total Contracts	70.3	17.9	11.8

Please note that this is an interim summary. The distribution may change somewhat with time.

6.2.2 Disputed Claims

In any contract of this magnitude there will be disputed items of both a contractual and technical nature. The main system contract required a referee be appointed to adjudicate in matters which could not be resolved otherwise.

BCT and the system contractor mutually agreed on the selection of an independent engineer with appropriate experience who acts as referee on contractual matters. This includes the interpretation of the contract and settlement of claims. Either party can request that the referee intervene in an unresolved problem.

6.2.3 Property Acquisition Strategy

BCT Transit had to acquire some 235 parcels of land for the purpose of locating the right-of-way. These acquisitions take many forms ranging from obtaining total ownership of title through to acquiring temporary work site easements for access by contractors during construction. Ownership of the properties varies from that of single family private ownership, to major commercial entities and finally, properties owned by cities, municipalities and major railroads.

The line was located to take advantage of the existing Dunsmuir Railway tunnel to traverse the downtown core. Further along the route, an existing railway right-of-way was utilized. Both these strategies saved significant capital expenditures. In another instance access to an underground station was arranged through the basement of a major store with advantage of bringing potential customers directly into the store. At the downtown waterfront special provision was made for a potential future building over the tracks by pre-installing the building foundations.

The purchasing strategy was to obtain two independent appraisals for the owner and BCT. A price was then agreed based on the appraisals. Initially BCT did not have powers of expropriation but these were added later. Despite a major down turn in property prices during the program negotiated settlements were reached for 98% of the parcels without resort to the expropriation mechanism.

In the course of assembling the land for the right-of-way BCT has acquired additional land. Most of this is to be sold or leased for redevelopment in due course. As can be seen from Table I this will lead to a substantial recovery.

6.3 Quality Strategies

In a project of this nature quality objectives must be pursued consistently if the owner is to obtain the best value for his capital expenditure. The quality strategy must begin with the establishment of design criteria and performance guarantees and be followed through to detail design and specification. In the construction/equipment fabrication phases, inspection and quality assurance procedures must be applied. Commissioning procedures must be quality oriented. In a 'turn key' or engineer-procure-construct (e.p.c) type contract the owner has less direct involvement in design and must rely on the system contractor's guarantees. A fast track schedule will also result in pressures on quality of fabrication and construction.

BCT requirements for quality are based on a fifty year life for the system and high degree of reliability and safety in operation. Some aspects of the quality strategy to achieve this are described below.

6.3.1 Facilities Design and Equipment Selection

The main system contract is accompanied by a detailed set of design criteria and equipment performance specifications. At the outset, BCT carried out a review of the documents. A design review process was established by BCT utilizing Acres Consulting Services Limited to carry out review at the 25%, 50%, 95% and 100% completion stages. The review covered all guideway designs, tunnel and maintenance/control facilities. These reviews were carried out on a section by section basis. They dealt mainly with conformance with the design criteria and quality in terms of the owners requirement. As the design proceeded it was found possible to reduce the frequency of reviews for the stations to a single detailed review at the 95% level. The reviews covered design drawings and specifications. Construction schedules methods and costs were also monitored.

By mid 1983 there were a number of technical items which had not been resolved, arising from the design review process or from the as-constructed experience on the prebuild section of the line. A Technical Review Board was established by BCT to resolve these items. The TRB consists of five members drawn from BCT and the system contractor staff and consultants. The board reports to the BCT Project Administrator, who determines the items for review and receives the final recommendations. The TRB is confined to determining the best overall technical solutions. The disposition of the cost of implementing a solution is dealt with elsewhere. To date all matters of substance brought before the TRB have been satisfactorily resolved.

6.3.2 Prebuild

The early commitment to the prebuild section gave the opportunity to carry out a project within a project. The prebuild contained most of the elements of the overall projects, tangent and curved guideway, elevated station, track and controls, vehicles and operations and passenger flows. The quality of design, construction, manufacture and operation were all put to a practical test. Much was learned about all these aspects which could be put to use to improve the quality of the overall project. For instance, in the guideway structures, the bearings and pier cross head designs were improved. As a direct result of prebuild experience. The Technical Review Board was also involved in this. Operationally much valuable experience was gained from the summer months of operation during which two vehicles made were in daily service. Construction methods and tolerances were extensively examined as a result of the prebuild experience. As a result the beam casting tolerances specification was changed.

6.3.3 Quality Control, Construction and Fabrication

Throughout the construction, and fabrication and manufacture there has been a high standard of quality control inspection. Detailed procedures are provided for materials and workmanship inspection. BCT staff and consultants participate directly in the construction management with the System Contractors staff. BCT staff also participate extensively in equipment and vehicle fabrication quality assurance.

In addition to inspection, there is a quality assurance program in place. This covers all aspects of fabrication of equipment, materials, and construction workmanship, the purpose of quality assurance system is to check that inspection procedures and methods are being properly and regularly applied.

In the event of disputes regarding quality of materials the matter can be referred to a Materials Review Board. Representation from BCT and the system Contractor are appointed on an ad hoc basis to form the Board. If the matter is still not resolved it could be referred to the Technical Review Board.

Commissioning procedures are not fully developed at present but it is planned that BCT staff will work closely with the Contractor's commissioning teams to facilitate the acceptance of the operational system.

7. CONCLUDING REMARKS

The ALRT project has a very short schedule compared to other contemporary similar projects. It also has unique elements in the use for the first time of LIM motor, and steerable trucks in combination with a computer controlled system. For both BCT and the system contractor, this was the first project of such magnitude which they had undertaken. For the Lower Mainland it is the first experience with rail transit. All parties were starting from scratch and had to build their teams and organizational procedures very rapidly.

It is not surprising that there were many stresses and strains within both organizations. Despite this, the project has gone extremely well so far. There is every expectation that it will continue to go well and that the system will open on time in January, 1986.

Engineering Construction Management Projects at Singapore Airport

Gestion de la construction de l'aéroport de Singapour

Projekt und Management-Organisation des Flughafens in Singapore

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Boon Liang Lim, a 42 year old Singaporean, was educated locally. He worked with Bank Group: Management Services Subsidiary as a Project Executive, then a Project Supt. for the airline before becoming its Property Development Manager for almost 11 years.

SUMMARY
The new Changi Airport near Singapore was designed and built in four years, from 1977 till 1981. A technical description of the project and the construction management organization of the Changi Development Unit are presented.

RESUME
Le nouvel aéroport de Changi près de Singapour a été étudié et construit en quatre ans, de 1977 à 1981. La description technique et l'organisation de la gestion du projet de la „Changi Development Unit" sont présentés.

ZUSAMMENFASSUNG
Der neue Changi Flughafen bei Singapore wurde in vier Jahren, von 1977 bis 1981, projektiert und ausgeführt. Die technische Beschreibung des Projektes und die Management-Organisation der „Changi Development Unit" werden vorgestellt.

PROJECT HISTORY

The Changi before was the idyllic tropical seaside resort - rusticated in many ways shown by the kampong settlements, vegetable farms, fruit orchards and picnicker camps. The Changi now/after is the airport of the twenty-first century - a bustling terminal of 4,400 pax turnover per peak hour, 30,000 meals per day, 750 tons of freight per day and 80 aircraft movement per hour (capacity). What's How's and Why's went on behind the hectic 6-year transformation programme from May 1975 till July 1981 with the $1.500(B) total investment, including SIA Group of $0.500(B).

Buoyant air traffic forecast shown by Fig. 1 on annual air passengers, air cargo handled and aircraft movements make it extremely difficult to continue at Paya Lebar: firstly, resettlement squatter families of easily 50 times of Changi; secondly, a second runway would entail straddling over a river and the decade old MOE refuse dump; thirdly, the South flight path hovers above high density, high rise public housing and fourthly, relying on ad hoc and improvised expansion expedients is unsatisfactory. Changi offers tremendous prospects - it is a totally greenfield site. 900 hectares of land were reclaimed from the sea. The total airport area (Fig. 2) is about 2500 m x 6500 m or 1663 hectares. Each of the two parallel runways has a max. capacity of 40 movements per hour. A total of 46 passenger aircraft, 6 cargo aircraft and 3 maintenance parking positions are provided. A terminal building of 120 m x 204 m, five stores high, two finger docks each 580 m long, a hangar building and several other buildings were already realized in phase I. Air safety and noise protection are safeguarded and, above all, unencumbered expansion potential.

The project development and milestones are shown in Fig. 2. The abbreviations are explained in the index at the end of the paper.

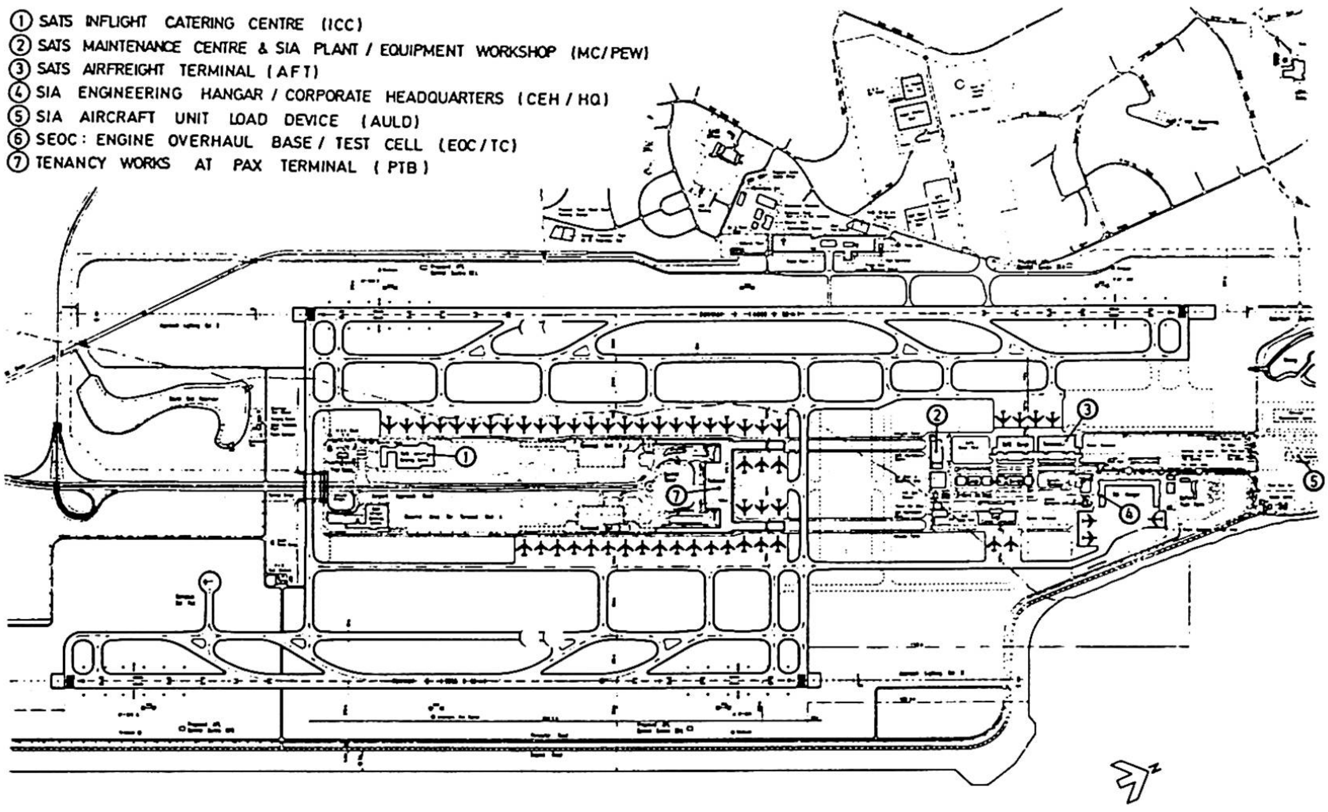

Fig.2 Masterplan Layout

• May 1975	– Cabinet decision on future airport at Changi instead of Paya Lebar
	– ECAD formed to formulate/control policies for Changi Airport development programme (more details in CDU organisation chart)
• July 1975/ June 1976	– Developing/Reviewing master plan – NACO
	– Block site planning through PDM with SIA Group users
	– Crash programme of land reclamation, 900 hectares over 24 months
• January 1977	– Finalise selection of system consultant on ICC, AFT
	– Justification for site allocation and alienation, firm up building design briefs including A&E definitives
	– Commence design consultant selection – 24 teams
• April 1977	– SIA Group official decision to form CDU and three months later joined by Turner assigned managers and seconded staff from SIA/SATS
• February 1978	– Ground breaking at ICC
	– Start Basement at PTB/in progress
	– Soil consolidation at Hangar
• August 1979	– Award of Changi Engineering Hangar – Main Contract
• February 1980	– Award of Hangar Roof, construction sites all in full swing
• February 1981	– Arrival of first roof sub-unit (650 tonnes) by sea
	– Test run of runway I, PTB, ICC, AFT
• July 1981	– Exodus Paya Lebar and Changi Airport starts
• September 1982	– SIA Corporate Headquarter starts
	– Changi Hangar starts

Table 1 Project History (Key Milestones)

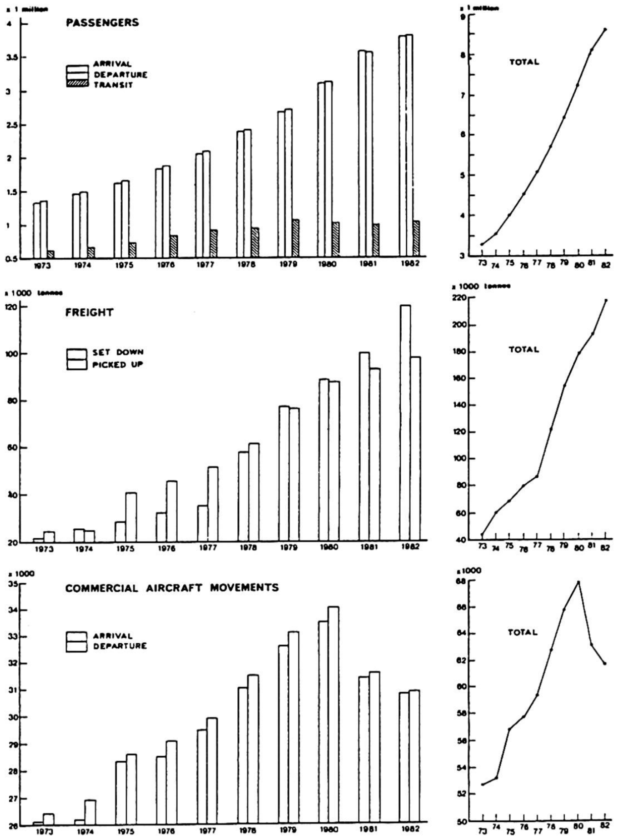

Fig. 1 Singapore Airport Statistics (1973-1982)

TECHNICAL DESCRIPTION

A few features taken from the key projects (Fig.3)

	m2	Cost (SIN $)
. SATS Airfreight Terminal (AFT)	42,000	72.000 (M)
. SATS Inflight Catering Centre (ICC)	50,000	80.000 (M)
. SIA Corporate Headquarters (CEH.2)	30,000	225.000 (M)
. SIA Engineering Hangar (CEH.1)	21,000	

Airfreight Terminal. Done on strictly "function first and form later" by commissioning BNP to do all economic studies/review, system engineering and only after completion of system flow and layout and the Building Design Brief, the Building Consultant got on board to wrap around the process flow layout. The first phase comprises symmetrically placed site, modules 2 and 3 capable of expanding to M1 and M4 to double up the initial capacity of 300,000 thru-put freight tonnes to 600,000 FT. The internal features show the modern methods of material handling system by elevated transfer vehicle (ETV) and high level storage racks through use of retrieval cranes.

Inflight Catering Centre.Similarly done as for AFT. System experts on mass meal production were appointed to carry out a thorough review of traffic analysis (by computer model simulation). A system of layout flow processers, storage support sub systems, wash-up subsystem was developed on a participatory approach with all related users. A building design brief containing the "A&E Definitives" was jointly developed with CDU before the Building Design Consultants were selected. The design development was exhaustive capitalising on the confluence of expertise from 4 sources: the System Experts, Inhouse Catering, Management Know-how, CDU Project Management and the long standing and eminent Architects, Engineers and Quantity Surveyors. Planned on modular grids the present capability of 30,000 meals per day can be easily expanded to 50,000 per day in the 1990's.

SIA Corporate Headquarters. Located at the upper 5 floors of the U-shape on plan, 10-storey annexe, SIA Head Office shows a modern office system approach. In conjunction with the Accoustic Consultants, the Architects and Engineers, CDU's inhouse landscape open plan unit (LMU) in consultation with a German team (QBT) implemented the first open plan office of the 30,000 m2 scale at the annexe. The physical results are achieved through fine tuned co-ordination efforts - LMU, Design Consultants, Contractors, the end users and the specialist open plan furniture vendors.

Changi Engineering Hangar (CEH). Again, the successful completion is accomplished through collaborative efforts of design consultants, specialist contractors and in the case of the tubular diagrid roof the unstinted contribution of the Checking Consultant Engineer. The Tubular Space Frame Diagrid Roof solution was the combined result of poor site condition and height constraint. However, the design, services co-ordination, fabrication and final site erection and lifting of the 2,500 tonnes of the 218(L) x 92(D) x 8(H) columnfree roof structure is a construction planning and management operation worth of attention to future practitioners or clients facing the same problem. Even the last expected activity could go wrong, if no advanced preparing as well as corrective action planning to face up situation had been provided. The case of protective coating is a classic example.

Soil Consolidation. Because of an underlying lens-shape section structure of thick marine clay, the site had to be subject to 14 months surcharge varying 6-8 meters high plus stitched down castle board drain at approximately 2.00 m centres at a total costs of $5.00(M).

Flying Table Forms. Owing to slow start-up due to site conditions and another reason, the Construction Team collaborated with the Contractor to use this system of formwork. Productivity rose from 31 days per floor to an all-time high of 18 days per floor at the 9th and 10th floor slab. Records confirm a time saving of 25% over the conventional formwork method.

EXECUTIVE PROJECT MANAGEMENT ORGANISATION

Ideals shown in our objective on design/approaches are one thing but follow-up action is another. There was the large scale of some 304,000 m2 of total gross built-up area scattered over six far flung sites. Another couple of worrysome features were the near $500.00(M) budget and the very tight time frame of 4 years for design and construction, discounting 1½ years for masterplanning of the total project duration.

While mobilising inhouse development expertise and user departments for masterplanning and building design briefs went underway it was at the 2nd quarter of 1977 when the Changi Development Unit (CDU) was set up and put into operation.

It was intended to be the pure type of project or indeed a construction management organisation to be run independently with minimum interference and maximum support from SIA/SATS top management. The organisation is accountable to both SIA/SATS management separately - implemented by monthly series of high level project management meetings (Fig. 3).

The Property Development Manager (Changi Projects) is represented in the Executive Committee on Airport Development (ECAD) to provide the organisation links (Fig.4). He also submitted monthly status as well as financial management report to the Group Chairman.

CDU's mission was to ensure effective project funds control, time schedule and quality of the works. All the three (3) wings, namely, Project Engineering, Construction Control and General & Administration are mutually supportive to carry out its mission during 4-5 years. Its own facilities included a 1.000 m2 two-storey CDU rented building, photostat and blue print equipment, word processor, 2 landover vehicles and some other sundry equipments/site facilities.

Some matrix relationship lines were inevitable as eventually the project engineers, construction superintendents had to work closely with end users, airport building authorities, innumerable consultant staff, contractors supervisory and management personnel.

In view of the different form of employment contracts, man-management grew sometimes to awkward proportions. The composition of the CDU at peak is:

(a) second SIA/SATS	44	
(b) contract personnel	52	
(c) assigned TEA	6	102

TEA personnel enjoyed relatively generous compensation being assigned through the project management contract, contract staff receive very high salary but reduced

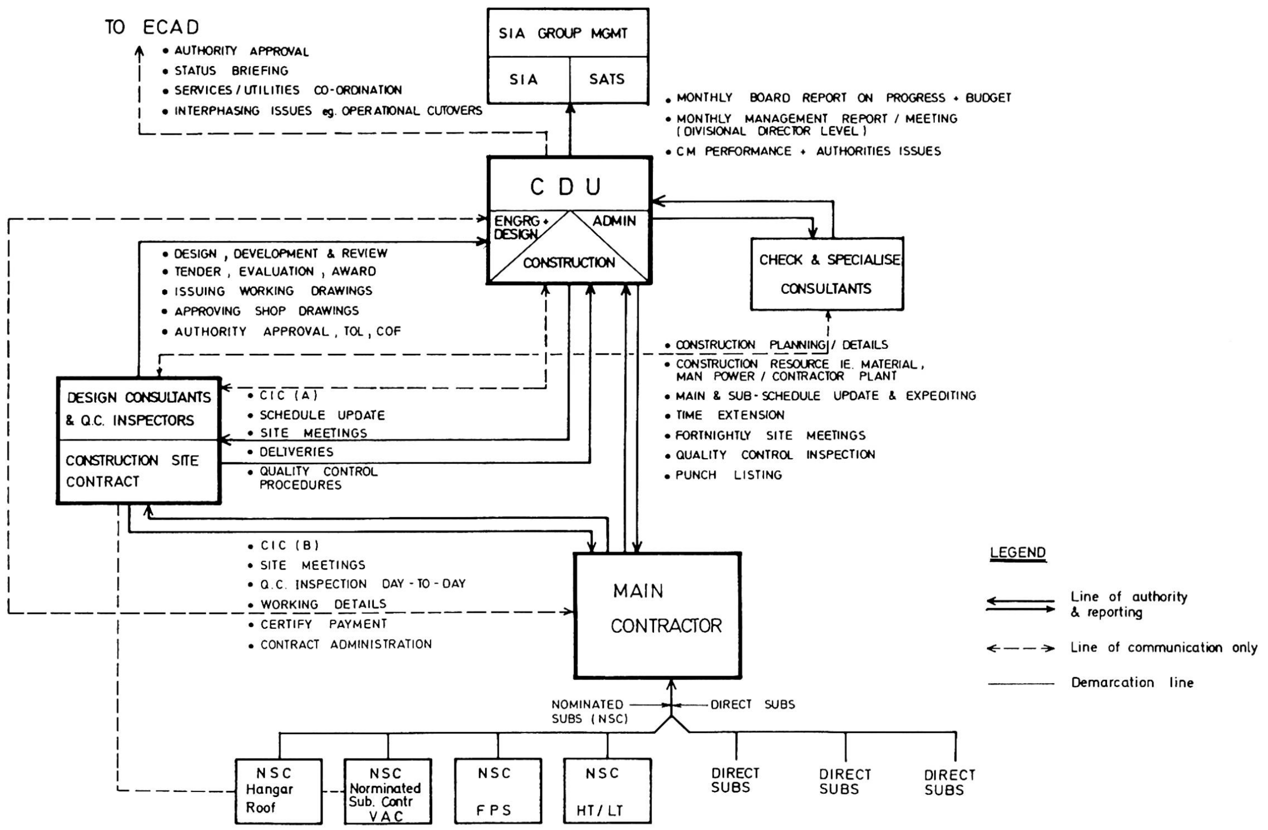

Fig. 3 Construction Management Chart for US$ 100M SQ Hangar & HQ at Changi Airport

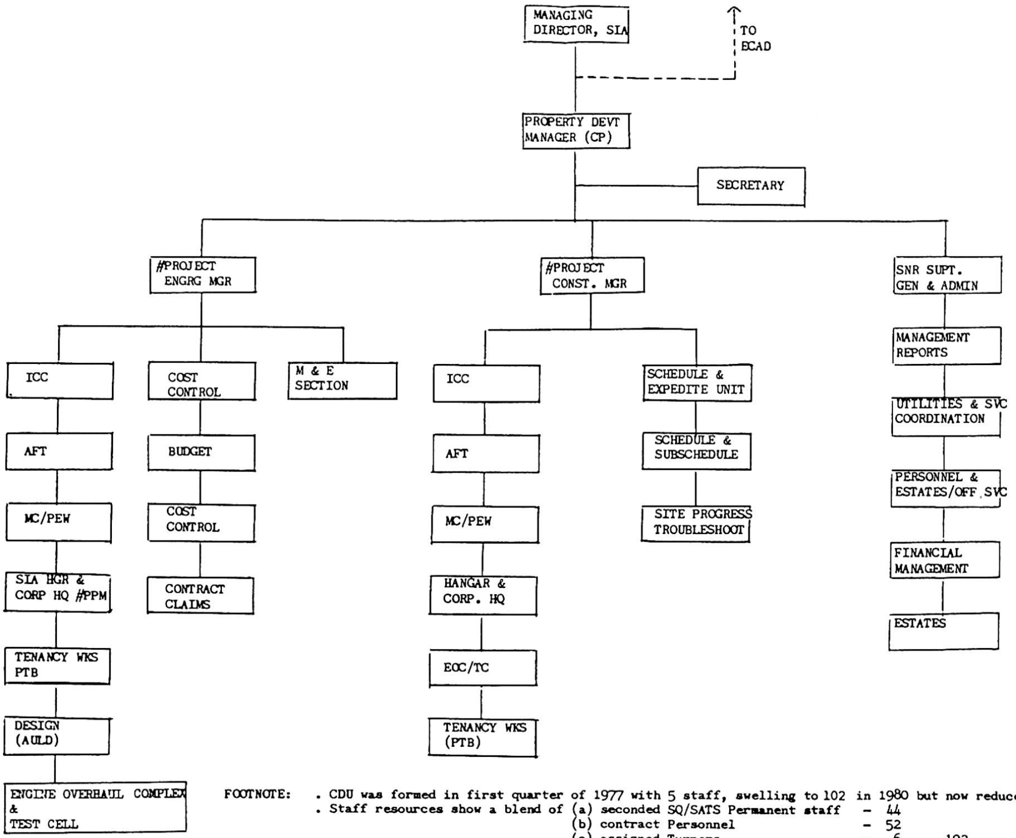

Fig. 4 Organization Chart of CDU

FOOTNOTE:
- CDU was formed in first quarter of 1977 with 5 staff, swelling to 102 in 1980 but now reduced to 6
- Staff resources show a blend of (a) seconded SQ/SATS Permanent staff – 44
  (b) contract Personnel – 52
  (c) assigned Turners – 6 102
- A dedicated, pure project and executive type organisation which is almost autonomous yet having a lot of matrix links with Users/Authorities
- Most contracts are done "design and build" basis

fringe benefits compared with the seconded permanent staff. All the conflicts were resolved after a series of meetings and compromises as the threat of quitting their jobs to disrupt the project was more real than imagined.

Imbued with humanist school of thinking, CDU Admin actively promoted several programmes to forge close knit team spirit i.e.

(a) Inter site sports competition and cross country run
(b) CDU Annual Dinner & Dance and X'mas Do's
(c) Visits to Homes of Handicaps, Aged, Salvation Army, etc

Quality Control Circles (QCC) and Open Appraisal Interviews were extensively used.

It is to be noted that all contracts were carried out on a "design and build" basis except the 747 Test Cell which was one on turnkey. Budget and schedule control were practised by means of cost commitment and payment reports, variance procedures, milestone/stage programme tracking and updating.

CONCLUSIONS

Experience is the greatest teacher of all lessons. Having lived through all the difficult phases of the projects, we realise that short lead times have to be treated seriously. Advanced preparation is the safeguard. Diligence and dedication cannot find substitutes in whatever project tools or systems.

In general appraisal, we have fared fairly well. The benefits of a well structured project management system are vivid. It represents results achieved through co-operative endeavours which are certainly greater than the total sum of the component parts. For the skeptics and followers alike, Changi Airport provides a living model of the synergistic efforts of international expertise, technological advancements and the local resources of people and marginal land availability.

LIST OF ABBREVIATIONS/ACRONYMS

ECAD	:	Executive Committee on Airport Development (headed by the Chief Permanent Secretary Singapore Government after being formed by Cabinet Decision in May 1975).
DCA	:	Department of Civil Aviation which is part of the Ministry of Communication.
CADD	:	Changi Airport Development Division i.e. specially formed by Public Works Department to do all Master Planning, Infrastructure, Pax Terminal and other services buildings.
CDU	:	Changi Development Unit formed by SIA Group Management to handle the Group's major projects worth over (B)0.500 Singapore Dollars.
MOE	:	Ministry of Environment
NACO	:	Netherland Airport Consultancy
A & E	:	Architectural and Engineering
M & E	:	Mechanical and Electrical
ATC	:	Air Traffic Control (Tower)
SATS	:	Singapore Airport Terminal Services
SADE	:	Singapore Airport Duty-Free Emporium
SEOC	:	Singapore Engine Overhaul Centre
TEA	:	Turner East Asia
CEH	:	SIA Changi Engineering Hangar
ICC	:	Inflight Catering Centre
AFT	:	Airfreight Terminal
MC	:	Maintenance Centre for apron handling equipment
PEW	:	Plant & Equipment for engineering ground equipment
AULD	:	Aircraft Unit Load Device i.e. aircraft container
PTB	:	Passenger Terminal Building
ETV	:	Elevated Transfer Vehicle

REFERENCE MATERIALS		SECTION
1.	Airport Forum 4/81	Background Data
2.	Proceedings of Airport Planning and Development Symposium - 1982	Background Data
3.	Department of Civil Aviation: Annual Report 1977 till 1982	Growth Statistics Background
4.	Implementation of Project Management by Project Management Institute, California USA	Executive and Autonomous Project Management Organisation and Organisation Styles
5.	Selected Readings of Human Resources Managment and Productivity by Bill Reddin	Humanist Approach and QCC's
6.	Managing Human Resources by Sayles and Straus	Humanist Style and Open Appraisal
7.	Project Manual on Financial Controls and PMIS by Arthur Anderson	Financial Controls
8.	Programming Method - HM SO	Scheduling Controls
9.	Management Techniques - by Oxley and Posket	Scheduling Controls
10.	Principles of Construction Management by Roy Pilcher	Programming and General Interest
11.	Management of Engineering Projects by Maurice Snowdon	General Interest
12.	Straits Times Commemorative Feature on SIA Group Projects - 1979	Background Materials

Saudi Arabia-Bahrain Causeway Management Aspects

Gestion de la construction de la liaison routière Bahrain-Arabie Saoudite

Aspekte des Managements des Saudi Arabia-Bahrain Dammprojektes

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Kjell Svensson, born 1943, graduated as M.Sc. 1967 at the Royal University of Technology, Stockholm, Sweden, specialized in Project Management of a projects different stages from design to construction-commissioning and has been responsible for several major commissions in his field i.e. university-hospitals, factories, airports, accommodation-service centers, hydro- and nuclear power plants and bridges.

SUMMARY
The Saudi Arabia-Bahrain Causeway which is to be completed by early 1986, will provide a 25 km long road link between the Arabian Peninsula and the island of Bahrain. This causeway built up of bridge and embankment sections carries a four lane dual carriageway. The construction contract, was awarded to the Contractor on basis of their alternative bridge design in prestressed concrete and featuring a highly industrialized construction approach. This article outlines management features of this international mega-type project together with some aspects of the Middle East construction environment.

RESUME
La liaison routière Bahrain-Arabie Saoudite sera complétée au début de 1986 et permettra de relier la péninsule arabique à l'île de Bahrain, distante de 25 km. Cette liaison comprend des tronçons de ponts et de digues permettant le passage de 4 voies dans chaque sens. Le contrat a été confié à l'Entreprise sur la base d'une variante de ponts en béton précontraint, et faisant appel à des techniques de construction très industrialisées. L'article présente certains aspects particuliers de la gestion de la construction de cet énorme projet, dans l'environnement du Moyen-Orient.

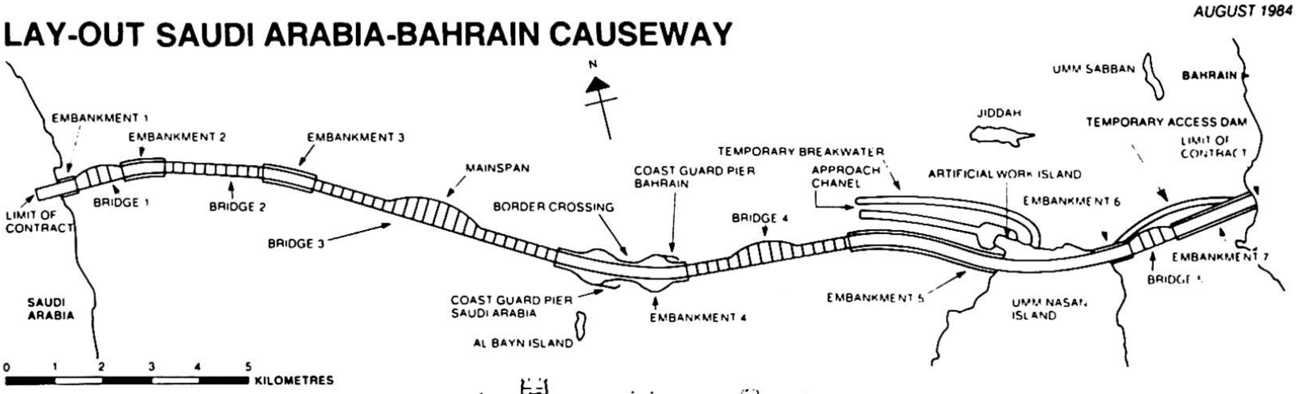
ZUSAMMENFASSUNG
Der Saudi Arabia-Bahrain Damm, dessen Fertigstellung für Anfang 1986 vorgesehen ist, schafft eine 25 km lange Strassenverbindung zwischen der Arabischen Halbinsel und der Insel Bahrain. Dieser Damm, bestehend aus Brückenabschnitten abwechselnd mit Dammbauten, wird vier Fahrspuren in beide Richtungen aufweisen. Der Auftrag wurde dem Unternehmer aufgrund seiner herausstechenden Konstruktionsvarianten für die Brücken zugesprochen. Die vorgesehene Ausführung in Spannbeton verlangt einen hochtechnisierten Ausführungsstandard. Dieser Artikel streicht Merkmale des Managements dieses internationalen Jahrhundertprojekts, unter dem besonderen Aspekt des Standorts im mittleren Osten, heraus.

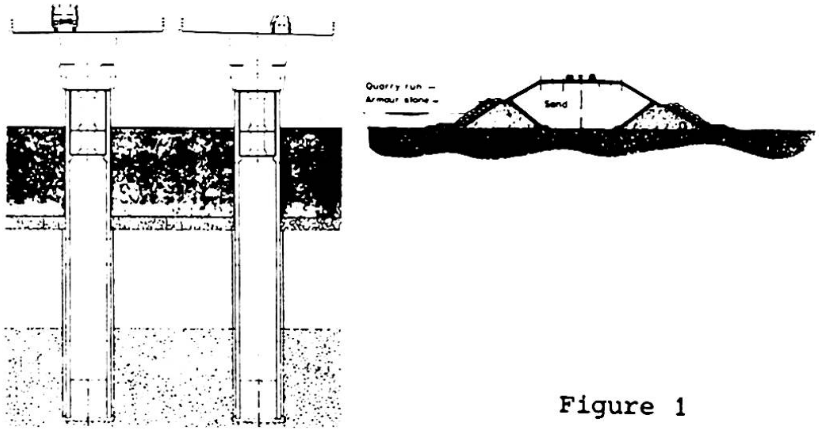
1. INTRODUCTION

1.1 History. The first plans for this major and prestigeous civil engineering project date back some twenty years. In 1974 Saudi Danish Consultants were appointed as the consultants, after which six and a half years elapsed for feasibility studies, design and pre-tender preparations. Tender documents were issued early in 1980 and sixteen prequalified international construction consortia and companies submitted their tenders in July of that year. After severe competition and extensive negotiations the contract was awarded to the Ballast Nedam Groep in July 1981, based on an offer comprising an alternative bridge design proposed by Ballast Nedam. The contract sum of US$ 564 x 10^6 was about 15% less than the lowest bid also made by Ballast Nedam but based on the tender design.

1.2 Scope of Work. The Causeway with a total length of 25 km comprises five bridge sections varying in length from 930 to 5190 m at a maximum water depth of 13,0 m and seven embankment sections with lengths ranging from 620 to 3130 m in a water depth up to approximately 5,0 m. Two navigation channels are included in bridges 3 and 4, with ship clearance heights of 28,5 m and 18,5 m respectively, relative to the mean sea level. Standard bridge spans are 50,0 m except for bridge 3 which has a main span of 150,0 m and two side spans of 80.0 m. The bridge design consists of prestressed concrete structures for both sub- and super-structures comprising a high degree (90%) of prefabrication with elements weighing up to 1300 tonnes, and with an advanced material specification to prolong the durability.

1.3 Construction Environment. Construction projects in the Middle East are mostly organized along traditional lines, that is a sequential scheduling of project phases from inception through design, construction and commissioning. Most construction contracts are of the FIDIC type, but sometimes considerably modified to suit local traditions, regulations and business attitudes. Ballast Nedam, together with other West European, American and Far East companies has successfully been executing, individually or in joint venture, a number of other large and complex projects in the oil producing countries of the Middle East, however not without a learning period for adapting to the scale enlargement effects and the local business and construction environment. The enormous development and construction booms over a relatively short period of time, together with a restricted local construction experience on the one hand, and the strong position of a demanding Client with his Arabic cultural and social background on the other hand, has made the positions and roles of the contractual parties develop somewhat differently from the West European pattern. The Clients, for instance, act much more directly towards the Contractor in both contractual and technical matters, sometimes assisted by additional advisors, such as quantity surveyors and and other specialists from international agencies. In these circumstances we see the consulting engineers forced to act as the technical supervisor only, rather than the traditional contractual and technical representative of the Client.
The contractor is thus directly confronted by a Client and an environment in which the socio-cultural features are quite different from his own. This may lead to unusual demands and complicated lengthy procedures for the processing of approvals for materials, variation orders, payments and permits. It is therefore necessary that both the contractor and engineer show the flexibility and the will to build up the necessary trust levels and informal working relations between themselves and the Client, as otherwise the project which in general is faced with considerable imports of labour, material and plant, will be subject to large procurement and logistical problems and thus delays and financial losses.





Total length	25 km of which 12,5 km bridge sections.
Embankments:	7 sections length: varying from 617 m to 3627 m waterdepth max. 5.0 m
Bridges:	5 sections length: varying from 934 m to 5194 m waterdepth max. 13 0 m (bridge 3)

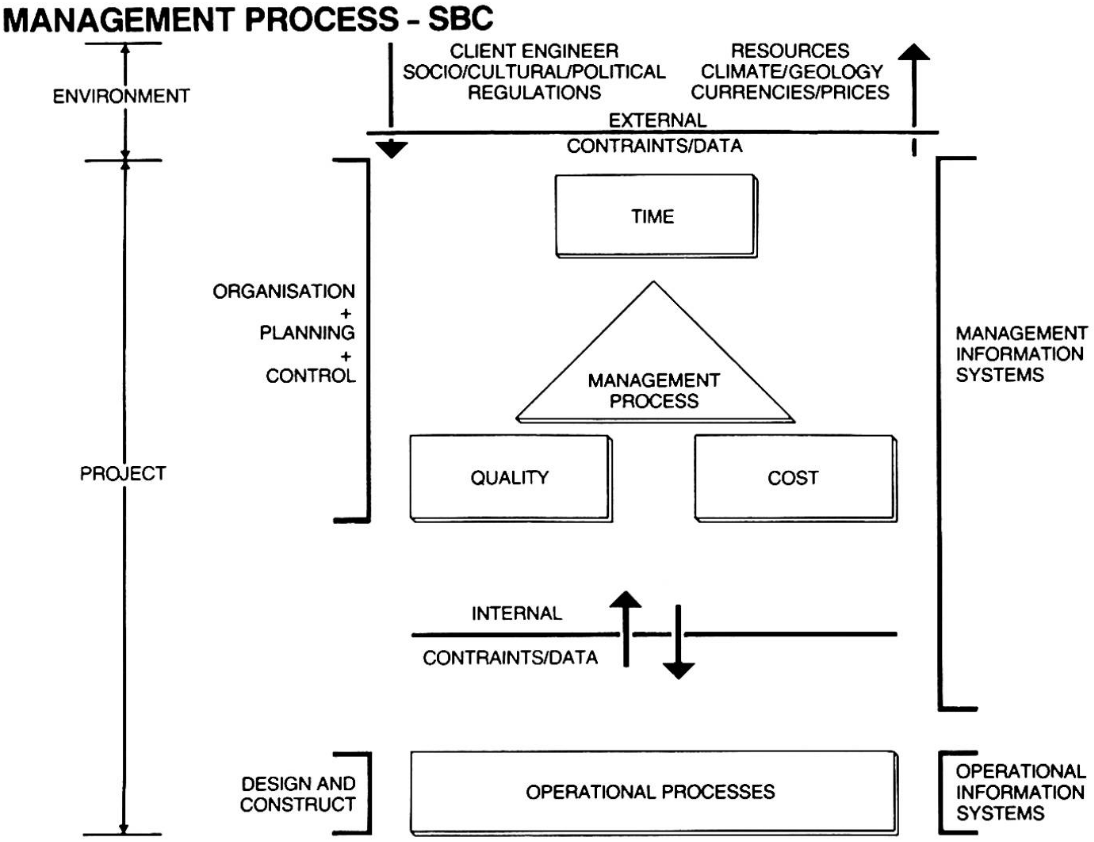
Navigational clearances:

bridge 3 (main span)	height +	28.5 m (to water level)
	width	135.0 m
bridge 4	height +	18.5 m (to water level)
	width	45.0 m

Road: four lane dual carriage way

Figure 1

Figure 2



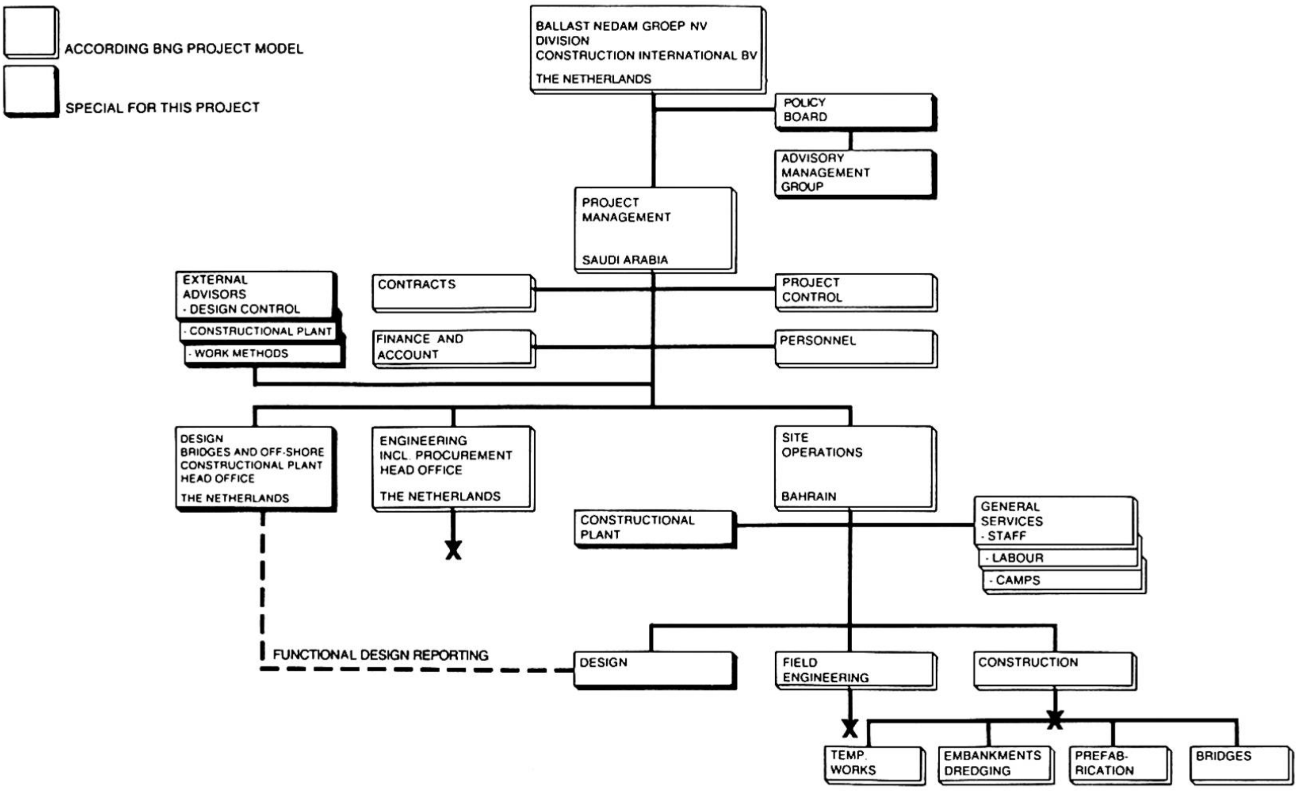
The project processes are presently subject to further contraints caused by the understandable policy on the part of the government to impose on foreign contractors the use of local materials, local agents for imports and local sub-contractors. To these impediments we have to add the more general aspects of international contracting, like the unknowns inherent in the one-time relationship between the contract parties, currency and price fluctuations, and political risks.
It will be evident that the combination of these external local constraints together with the organisational and financial demands and risks resulting from project scale enlargement render the execution of a contract in the Middle East a complex and vulnerable enterprise with regard to time, cost and quality, consequently a project approach by means of a clear management concept based on local experience is essential. This concept should recognize the influence of internal and external constraints and the necessity and ability to control them, which can be summarized by the simplified process model (figure 2). This model separates the management functions from production and furthermore distinguishes the well-known project parameters of quality time and costs with the required information systems to control them.

2. PROJECT MANAGEMENT

The experiences of the last 10 years with large scale projects within Ballast Nedam has led to the implementation within our company of a model organisation structure (figure 3) with master procedures and systems for such projects. The project managers have to use this model as a framework for organizing their projects. With this model an effective utilisation of available know-how and systemized project information and reporting is achieved for not only the various projects levels but also the higher divisional levels.

BALLAST NEDAM PROJECT ORGANIZATION - SBC

Figure 3



2.1 Organisational Structure. The project model can be clearly recognized within the organisation of the SBC-project, see figure 3. Engineering and construction have been split up into four managerable and technically independent operations being:

- temporary works, including the reclamation by hydraulic fill of the work-island (1.6 x 10^6 m^3), access dams (3.3 km), dredging of the access channel (5 km), erections of prefabrication facilities on a 300.000 m^2 area, workshops, camps, offices etc.
- on-shore fabrication of concrete bridge elements
- off-shore erection of standard bridges and main span bridges
- embankments, including the quarrying of stone and dredging.

Essential to the site operations of Middle East projects is the Department of General Services, which is responsible for all staff and labour recruiting, board and lodging and the human relations within the multinational community which is created for these projects. The Contract Department plays a vital role in managing the external constraints apart from administrering the contract and sub-contracts. Another model feature is the project control department, which although directly serving the project management has also a functional responsibility towards the divisional control section to safeguard the quality of management information.

The special features of each project have always to be laid-out and compared with the basic features of the standard project model and the available staff resources to establish whether any changes or additions to the standard model are necessary to arrive at an effective organisation.

For instance the SBC-project, without a time-extension for the required design, was faced with severe time restrictions for establishing final project policies and decisions on key aspects such as:

- detailed consequences of acceptance of the alternative design,
- choice of work methods in combination with company investments for constructional plant,
- final specifications for the reinforced concrete, yet to be decided by the client,
- all items or decisions which either would have great impact on programming, cost and quality or would have a direct bearing on the overall investment programmes and liability of Ballast Nedam as a company.

The above mentioned aspects can be directly projected and summarized and will then give the following list of items of which some are general for large international projects and some are unique to SBC-project, but still have an influence on the risks and the ultimate result:

PROJECT INFLUENCE ASPECTS	TEMP.W.	BRIDGES	EMBKS
Off site (home office or elsewhere)			
*1) Contractor's design/durability responsibilities	x	x	-
*2) Work methods/plant section	x	x	0
3) Interrelations technique/time	x	x	-
4) Logistics: non-local material and plant	x	x	0
5) Engineers approvals	x	x	0
On-site (Bahrain/Saudi Arabia)			
*6) Quality assurance (climate, soils)	0	x	0
*7) Interrelations technique/time	x	0	-
*8) Logistics: local and non-local material/plant-spares/labour	x	x	0
9) Maintenance/Repair of Plant/Services	x	x	0
10) Sub-Contracting	0	-	x
11) Engineer's/Client's approvals	0	x	0
12) Government approvals/permits	x	x	x
13) Cultural/Social/Political constraints	x	x	x

x/0/- = large/normal/limited influence on cost and/or risk
* = typical SBC features

The normal course of action, reporting and decision making via our normal project model and company hierarchical lines were not considered feasible in terms of the required speed and quality of these decisions. To be able to cope with this situation an ad hoc policy group was formed on divisional level headed by the head of the international division, which was responsible for the project, supported by an advisory group consisting of the project manager, the heads of design, engineering and site-operation departments, technical and financial specialists (figure 3).

Within the framework of the milestone planning of the project the advisory group managed to prepare reports to an extent and quality that allowed fast and timely decisions by the policy group. Also special recommendations were prepared such as postponement by 30 weeks of the start of pile production and off-shore installation to allow ample time for optimum design- and equipment-engineering. Both decisions, for which firstly the Client's approval had to be obtained, contributed greatly to the quality and smooth progress of the works on site.

2.2 Design Guarantee. As well as the design for the bridges the contractual design guarantee was also transferred to Ballast Nedam. To assure the necessary internal design quality standards and controls, within our project model a separate engineering department was created with its own responsibilities towards the project management. The latter was charged with the proper coordination between design and engineering departments to optimize the project results (figure 3). To further limit the risk connected with the design guarantee, Ballast Nedam appointed an independent civil engineering consultant to make a check on all vital structural systems and elements. This check, together with the contractually required approval by Saudi-Danish Consultants was considered to be prudent to safeguard both Client and contractor from any calamities due to design errors.

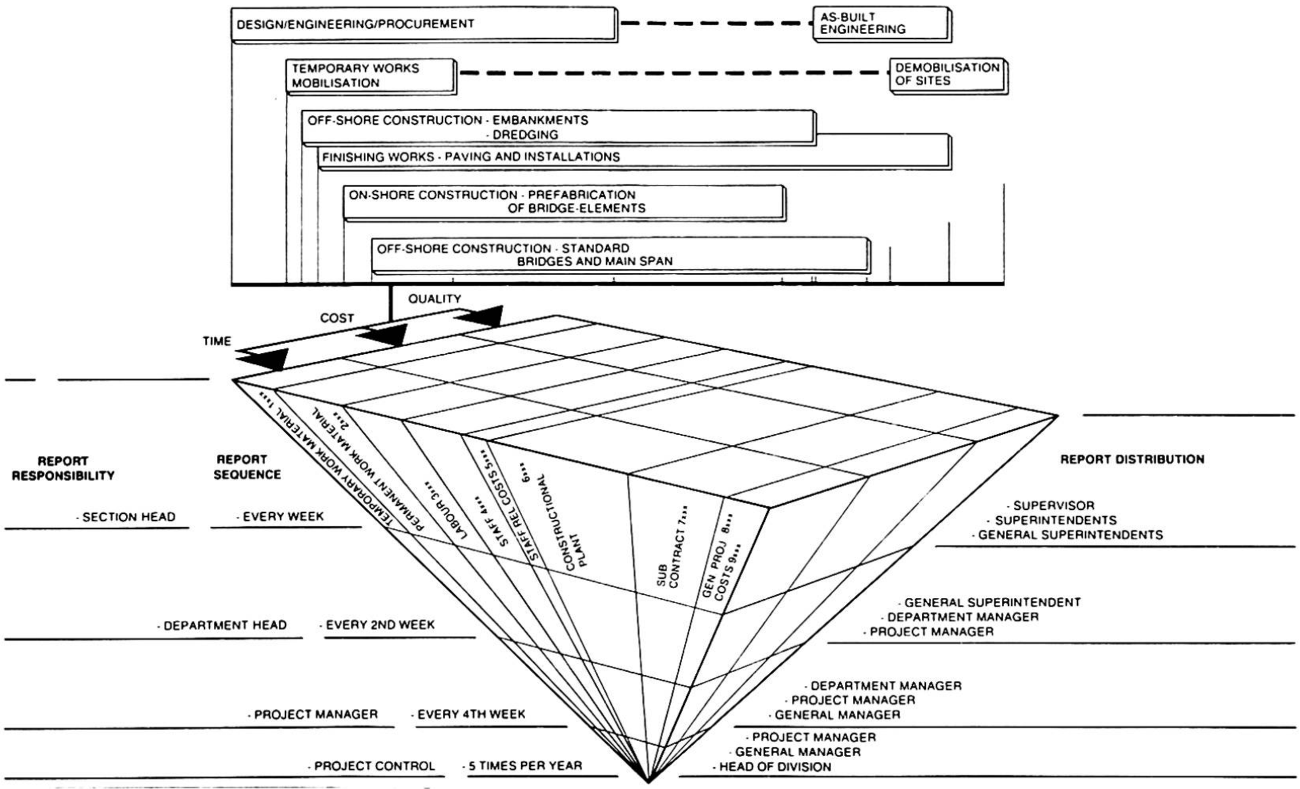
2.3 Planning & Control. The vulnerability of the project due to the scale effects and constraints as described required great emphasis on coordination of planning and control of time, costs and quality throughout all stages of the project (figure 4).

The time planning and monitoring systems are built up in two sections, the contract system in accordance with the Client's approved programme, and Ballast Nedam's own target system (figure 5). Within these there are three different levels; from detailed day-to-day programs up to overall summary schedules. Resources are allocated and linked together by milestones and built up from work method manuals and logical networks for the different operations.
The cost model with a planned sequence of detailing the tender estimate, parallel with the design development up to a fixed status called the work estimate, formed the allowed budget and reference basis for all periodical follow-up. The model included a coding system which facilitated a detailed split up per operational job item, as well as aggregated summaries per discipline, resource and responsible organisational unit.

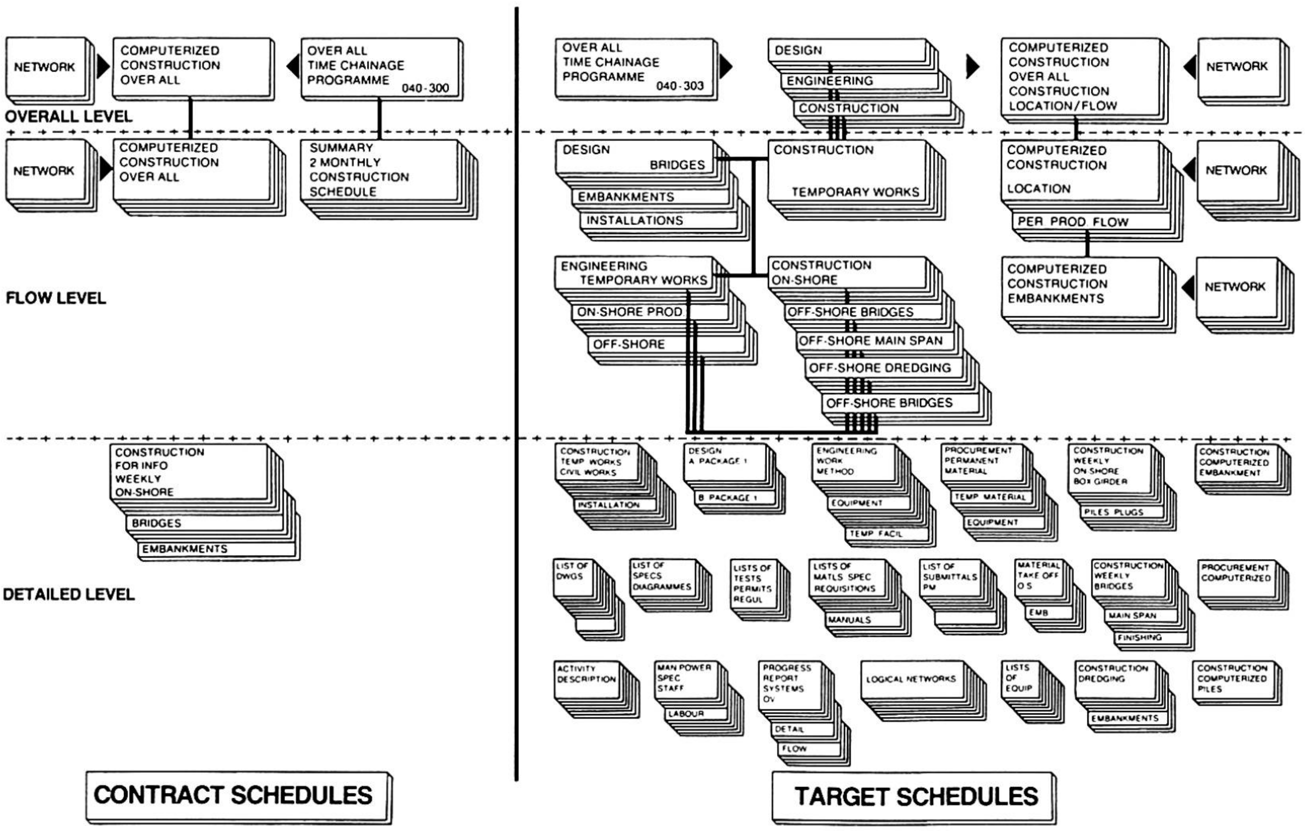
The quality control is based on programs linked to the design, engineering, and construction stages of the project and to the specifications and test procedures for permanent and temporary materials, equipment and work methods, as well as the final product. The quality control program is controlled overall by a Quality Assurance Group for local as well as non-local tests executed by Ballast Nedam, suppliers or independent laboratories.

The above mentioned models (figure 5) and systems mentioned above are first coordinated overall, then detailed to operational units and finally rechecked against the original milestones allowing the possibility to adjust the milestones at an early stage. To process and generate the information flows a computerized information system is required (figure 6) complemented by manual summaries for the trend and deviation reports, selected for the various levels within the organisation (figure 4 and 5).

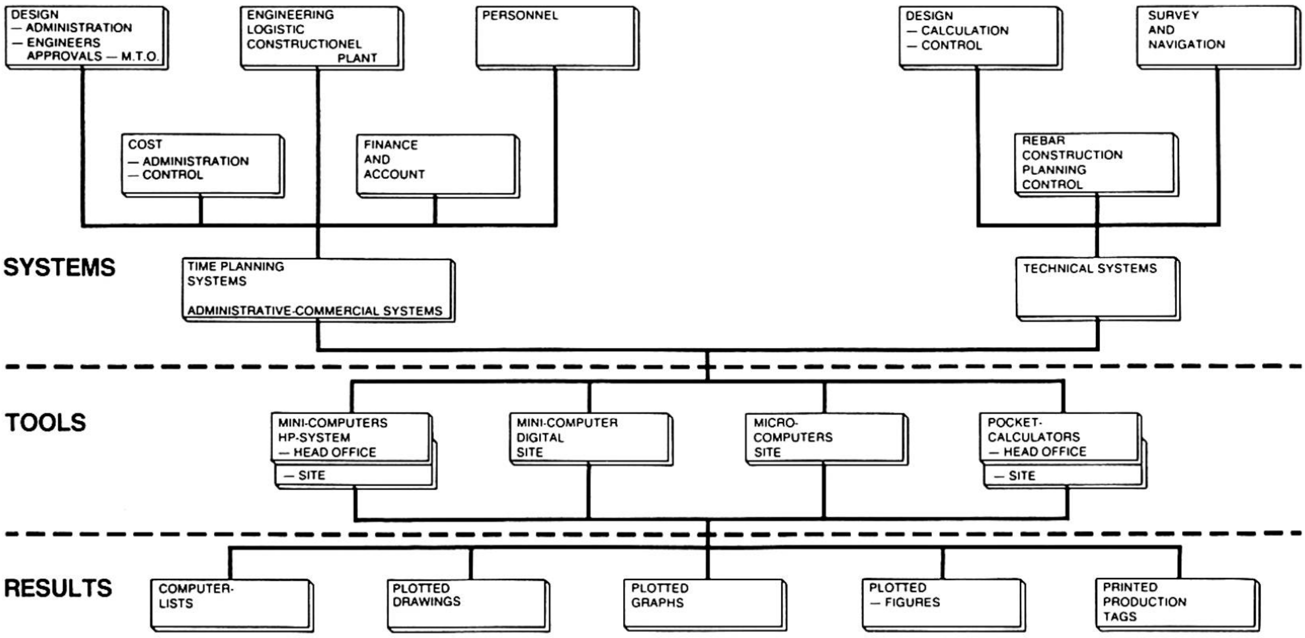
PROJECT MANAGEMENT CONTROL- AND REPORT STRUCTURE - SBC *Figure 4*



PROJECT OVERALL TIME SCHEDULING MODEL - SBC *Figure 5*



COMPUTER SYSTEMS SUMMARY - SBC *Figure 6*



3. ENGINEERING MANAGEMENT

The proven importance of a well organized and accurate Engineering stage was emphasized in this project due to the additional design as well as equipment and material engineering programs resulting from the acceptance of the alternative bridge design. At the same time the huge site preparation and soil investigation programs had to be executed. How vital the management of this project phase was, is reflected by the cost commitment curves (figure 11).

3.1 Design Engineering. Within the milestone fixed in the overall program, detailed breakdowns and planning of activities were made for sub- and superstructure design calculations and drawings, material engineering and testing, all summarized per responsible department and the actual progress monitored against planned progress.

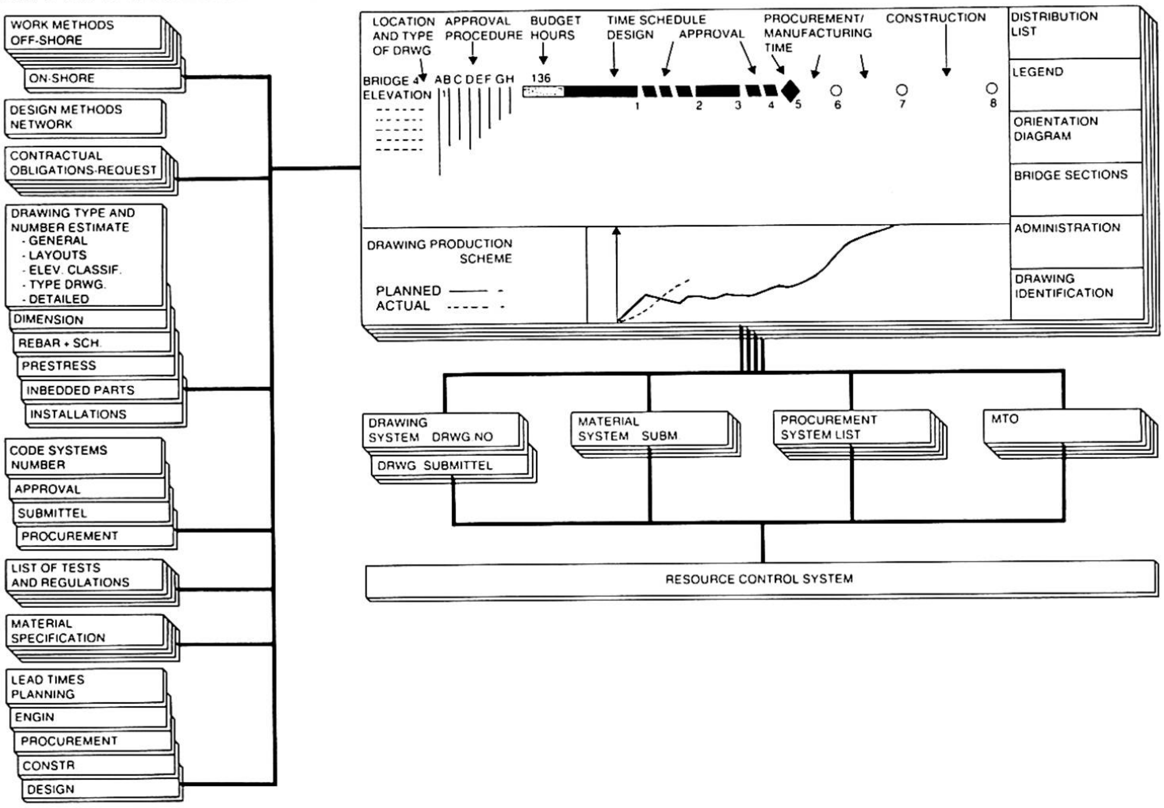
Furthermore, it was again experienced that one of the crucial activities within the engineering processes was the obtaining of approvals from Engineer and Client of tests, drawings, material specifications as well as construction methods. This was solved by an early agreement with the Engineer on a separate submittal system, which provides the control over the approval process time and qualitywise (figure 7).

Additional pressure on the organization during this stage was caused by a number of variation orders which had major consequences on the design concept, such as the shifting of the main span to bridge 3 including an increase or this span from 90.0 m to 150 m and the acceptance of our durability recommendations, which modified the material specifications and testing requirements considerably all without time extension for the completion of the contract.

3.2 Equipment Engineering. Parallel and coordinated with the design, the work methods were developed for prefabrication, transport and placing of 7000 precast elements consisting of more than 30 different types with weights up to 1300 tons per piece. Specially made construction plant worth over US$ 70 million and temporary facilities for on-shore as well as off-shore worth about US$ 50 million had to be designed, ordered and manufactured within nine months. The requirements were established per operation process and finally compiled in drawings, specifications, work-methods, equipment lists, manuals, departmental organisation routines and time schedules, all in relation to the overall programme.

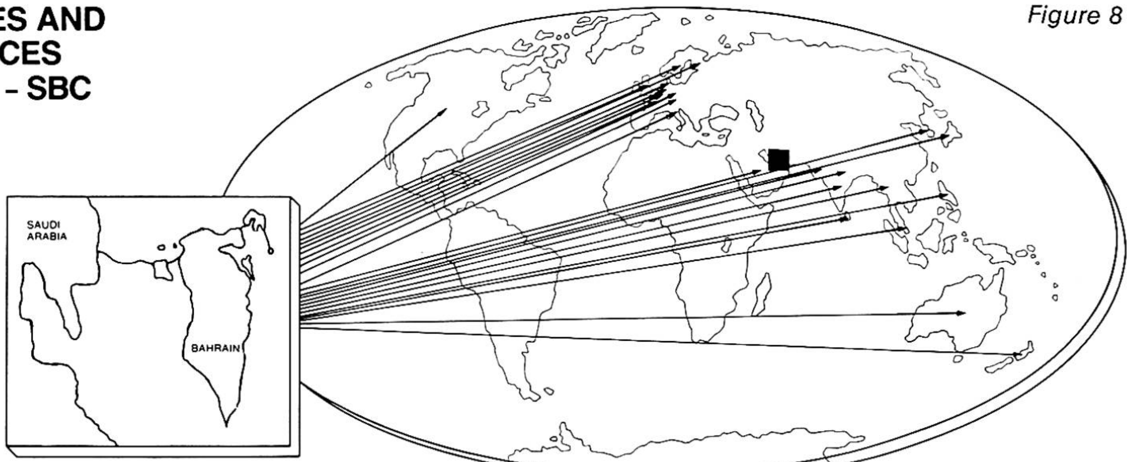
DESIGN MANAGEMENT SYSTEM - SBC

Figure 7



RESOURCES AND THEIR PLACES OF ORIGIN - SBC

Figure 8



STAFF AND PERSONNEL

The Netherlands	Staff
U K	Staff
West Germany	Staff
Finland	Staff
Sweden	Staff
France	Staff
Italy	Staff
U S A	Staff, Client/Advisors
Australia	Staff
New Zealand	Staff
Saudi	Client/Advisors, Labour
Denmark	Client/Advisors
Philippines	Labour
Korea	Labour
Thailand	Labour
Nepal	Labour
Sri Lanka	Labour
India	Labour
Singapore	Labour
Bahrain	Labour
Pakistan	Labour

MATERIALS

Saudi	Stone and rockfill, cables, lighting columns and fittings
Bahrain	Stone and rockfill, consumables, paint, PVC-pipes
The Netherlands	Cement, reinforcement steel, posttensioning - system, general fittings for construction, mortar, injection resin, guardrails, filter fabric, concrete spacers, lenton coupler, blasting grit
West Germany	Inbedded parts and fittings for posttensioning systems, dywidag-posttensioning bars, imbedded parts and fittings expansion joints
Switzerland	Epoxy- coating/piles, posttensioning system (cona-multi) Epoxy glue/main span
U K	Additives for concrete and mortar, reinforcement steel, grout mortar, repair mortar, epoxy resin
Sweden	Welding material, navigation lights
Italy	Elastometric bearings
Belgium	Formoil
Japan	Posttensioning wire and strands, electrical cable
United Arab Emirates	Aggregates for concrete, repair mortar, epoxy resin

EQUIPMENT, SPARE PARTS AND SERVICES

The Netherlands	Selfelevating platforms, girdership, tug boats, 1400 T main gantry and 80 T gantry pontoons, small working boats, diving equipment, moulds and formworks
Singapore	Dredger from idle area
Japan	Sheerleg, desalination plants, forklifts
U K	Rebar sheerline, rebar optimising computer, micro computers, under water video system
Italy	Rebar coil stretching and cutting machine
Sweden	Survey instruments, welding equipment
Australia	Computersystem
U S A	Mini survey positioning system, computers, mac trucks, cranes, engines, compressors, positioning systems
West Germany	Wirth drilling equipment, batchplant, swing pumps, aggregate washing equipment
Switzerland	Survey instruments
Finland	Skylift

SUB-CONTRACTORS, SERVICE-CONTRACTORS

South Korea	Dong Ah placing of wet embankments
Saudi	Truck transports of rock and stonematerial
Bahrain	Truck transports of rock and stonematerial diving service contractor, asphalt sub-contractor
U K	Survey service-contractor
Australia	Survey service-contractor
United Arab Emirates	Computer service-contractor
France	Bachy soil stabilising foundation sub-contractor

3.3 Procurement, logistics. These had to be organized for the import of all materials and equipment for permanent work, as well as all main materials and equipment for the temporary works and maintenance. These imports comprised about 30.000 tons of goods per month. The whole operational structure is coded and based on a requisition system, split up into local and non-local purchase and divided per code into twelve different stages from purchase submittal up to use on site. A market survey of possible suppliers, manufacturers, and sub-contractors was carried out, organized and sorted per material and discipline. The different companies were then gradually selected, approved by the Client and finally incorporated in the detailed design. This entire operation was administered by a computer system based on lead times for the procurement stages.

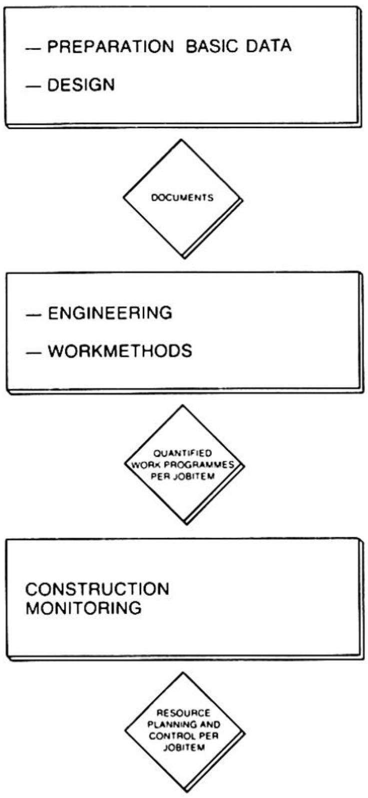
Schedules were developed on site for material deliveries based on a material take-off from preliminary drawings, broken down to usage per unit to be produced on-shore as well as off-shore. These were linked to target production schedules summarized per material code and displayed in graphs. To ensure the material would be on site in time, in the correct quantity and quality, three different consumption graphs were produced per material.
The maximum production rate graph, calculated minimum stock quantities, quality tests, means of transport inclusive of shipping and clearing time, gave the site requested delivery times.

For local purchase and material deliveries a corresponding but simplified system was developed and included a recording system for stock control and usage and distribution of materials to different departments, as well as per supplier.

In addition to this and in order to streamline the quality, reduce the unit prices, secure the deliveries, reduce administration costs and the stored quantities etc., a local supply contracting system was introduced for 30 areas of consumables. This covered about 80-90% of the total requirement and gave fixed annual prices achieved in competition.

OVERALL SYSTEM CONSTRUCTION CONTROL - SBC

Figure 9



All shipments were continuously recorded and controlled via a computer system supplying information about quantities, values, means of transport, arrival dates, bill of entry, custom duties and custom handling charges, letters and bank guarantees for clearance etc.
Staff and labour requirements were extracted from the work estimate, allocated to time schedules and summarized. They formed the basis for recruitment either within Ballast Nedam or externally through service contracts or agencies in Europe and the Far East (figure 8). However, before the final re-cruiting of for instance the 1400 men labour force, they were tested by Ballast Nedam's own staff.

4. CONSTRUCTION MANAGEMENT

The construction stage, organized and split up into temporary works, on-shore and off-shore production, was first functionally coordinated and then on a time and resource basis. Timewise by means of logical networks based on work method statements, manuals, organization schemes and through production unit rates displayed in time schedules.

Resources, coded and defined into job items in the cost model, are extracted and linked to the planned in order to get the planning usage rate per time unit, which is then controlled and followed up periodically. This basic work preparation was carried out in phases during the design engineering stage and adjusted based on experience gained during the start up of construction (figures 9 and 10). It was then monitored by work analysis studies comprising workmethods, usage of labour, materials, equipment etc.

For example, to organize and minimize the losses of rebar in the prefabrication of reinforcement cages, a special computer program was introduced, which after computerizing the rebar bending schemes for the different types of elements could link them together in accordance with the time program. The computer could then summarize the requirements per diameter and combine them in order to utilize the maximum length of the bars. The program also took into consideration the elongation due to bending and the tolerance allowed for in the norms and specifications. The computer not only printed the different types of reports for the supervision of the work, but also cutting and bending instructions for the operators and 6-colour printed identification tags for the rebar bundles, as well as showing the location for welding and further prefabrication up to the finished element.

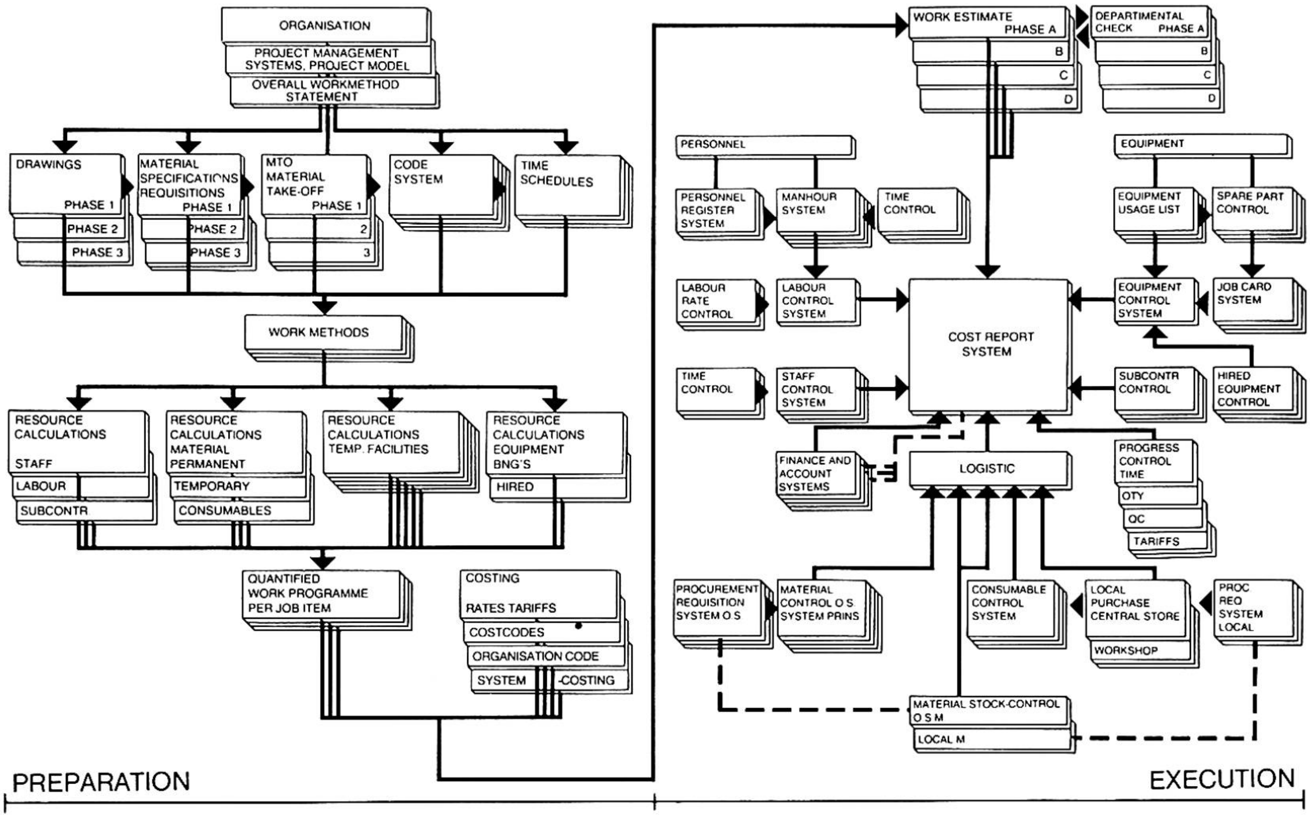
For follow-up and trend analyses of the labour force performance, the daily time record sheets per job item were summarized in weekly labour time sheets, recording all spent hours per job item. These were then computerized and sorted into different report levels as well as being compared with planned and actual measured progress of work. For the trend reports, cost comparisons of labour cost rates using tariff models were used. A corresponding system for equipment was also developed.

The follow-up of production, timewise, was correspondingly made on report levels from day-to-day records, such as cut and bent tonnage of rebar steel, cast m^3 concrete and weekly records of Client-approved elements. Progress is measured per day, per week, per fortnight and compared with the contract schedule as well as the different target schedules (figure 11).

Insurance claim handling, including recording, lodging of claim, estimation, negotiation with underwriters, loss adjustors etc., is an important part of the cost control of construction. Not only because of the total amount of premiums to be paid for the fifteen policies in use, but especially because of the strong possibility that accidents and incidents will happen which have cost consequences ranging up to hundreds of thousands of dollars. Accordingly, a computer system was developed to record and monitor the insurance handling.

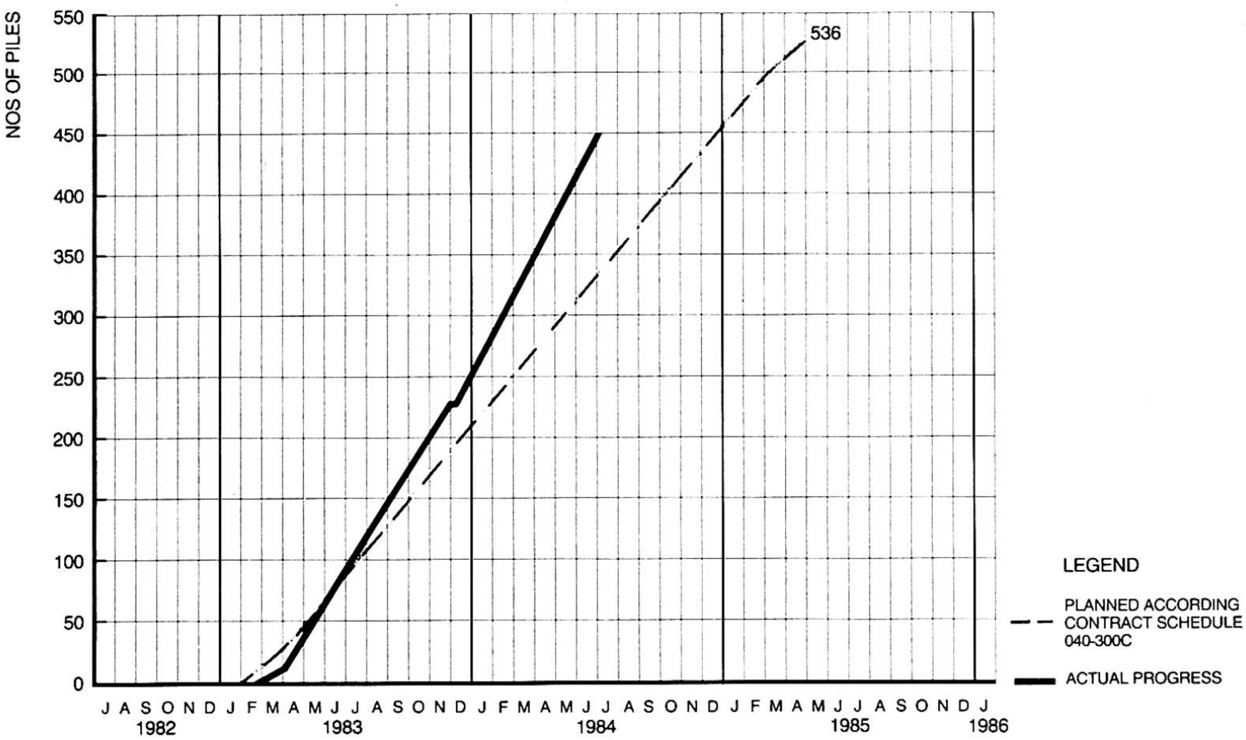
SYSTEM FOR COST CONTROL - SBC

Figure 10



PROGRESS CHART PILES - SBC

Figure 11



5. SUMMARY OF EXPERIENCE

Although there are still about one and half years to go on the contract, the following conclusions of experiences gained can be made, summarized into six major areas and in the decision - milestone summary (figure 12).

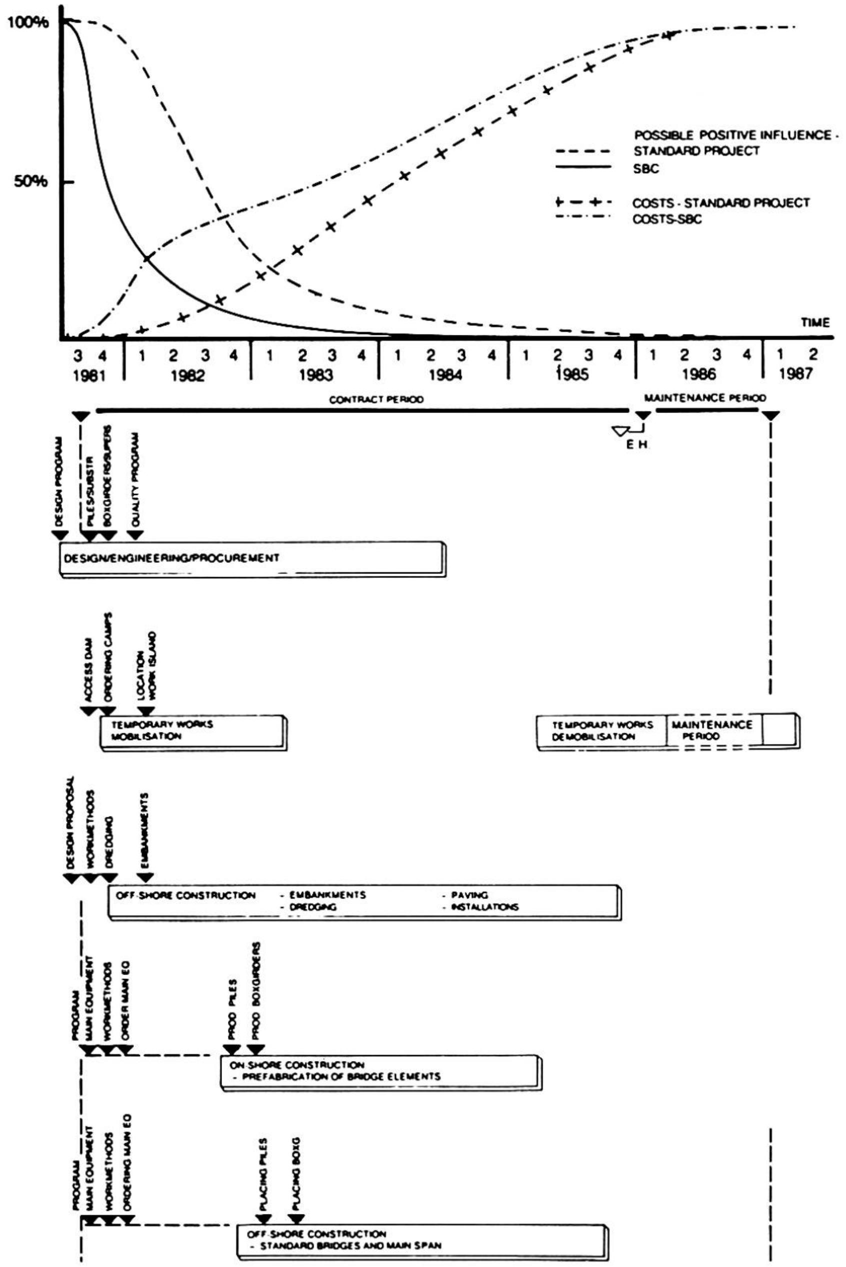
5.1 Integration of Design-Construction. In this project no allowance was made by the Client in advance for carrying out an alternative design, the original construction time of 225 weeks had to include this as well, which up to now shows the following:
- the necessity of a total, integrated design-construction approach with phased stages linked via engineering-procurement to construction, in order to ensure correct information for management decisions to be taken within the first few months, but ruling for the remaining years of the project,
- time saving, the total project time can be reduced, presently the sub- and superstructures are 24 weeks and 8 weeks respectively ahead of schedule, estimated time for handing over, (E.H.) see figure 12, is 6 weeks ahead of contract requirements,
- cost saving, about 15% through combined utilization of the design qualifications and the experience from the construction market (see figure 13).

5.2 Extensive Early Preparation and Logistic. The overall work method statement which was the basis of BNG's design alternative called for an on-site manufacture of prefabricated items, limited in numbers of variations to fit a modern industrialised factory production, but flexible enough through a special technique of assembling the items, to accommodate changes required later in the project when the phased design and soil investigation had been finalized. The success of the site operations both in time, cost and quality again underlined the emphasis of proper time and budget allowance for an early extensive preparation and corresponding logistics to be used for:
- workmethod studies, especially for those with multy usage of materials and equipment,
- coordination and development together with vendors and suppliers, especially for alternative future use of expensive equipment,
- tests and 'dry runs' of material, equipment and even personnel before sending them overseas because the possibilities for correction locally are limited, time consuming and costly,
- full scale tests on prefabrication and of equipment,
- early approvals from client or engineer for design and engineering principles and test procedures.

5.3 High Quality Demands Versus Execution. The high quality standard and durability demands specified in the Contract and later on increased in variation orders to the Contract were met by an:
- extensive market survey of alternatives of materials and constructional plant including tests, analyses and assistance by external advisors,
- phased design and work method engineering,
- maximized prefabrication, because of the ability to better influence and control the tolerances and quality in the factory than in-situ made off-shore,
- improved accuracy of off-shore placing of the elements both regarding quality and time.

5.4 Project information System. In order to be able to monitor, control and communicate the huge amount number of information, data etc. generated in a project like SBC a well operating project information system is required. Organised in details to suit the day to day operations as well as hierarchly coordinated to enable production of selective summaries, for the different levels within the project organisation, as reliable bases for trend analysis and influence on decisions and actions.

DECISION MILESTONE SUMMARY - SBC *Figure 12*

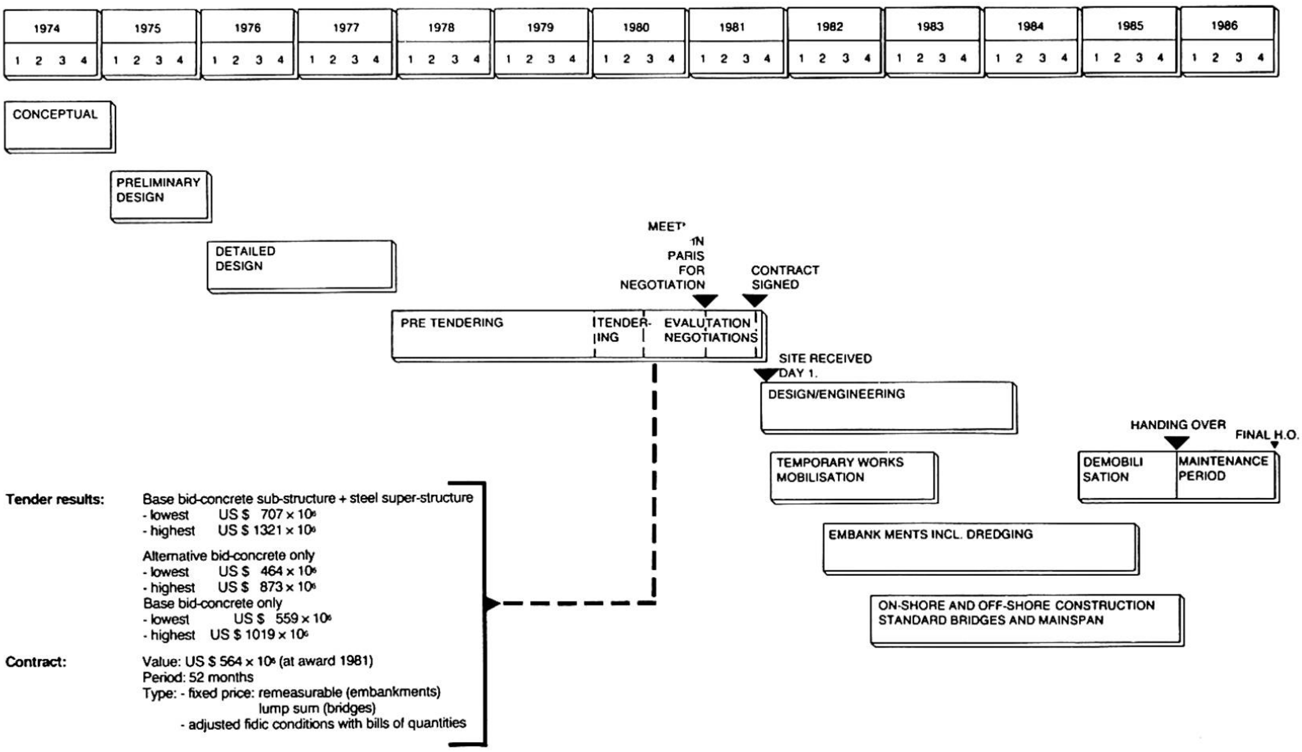


5.5 Established Approval Procedures. The nature of this project as has earlier been described was complicated not only by reason of responsibility due to Ballast Nedam's design alternative versus the Engineer's proposal, the geographical spread of the parties and resources involved, but also by the short period during which the principles and alternative proposals had to be approved by the Client or Engineer.
Those constraints were met by early well established approval procedures including:

- phased approval procedures, for design calculations and basic drawings in Europe, detailed design work methods on site in Bahrain, and variation orders, suppliers, sub-contracts and permits in Saudi Arabia,
- scheduling within the overall work program of all items and approval routines including checking, revision, approval and final delivery of documents and samples.

PRE-CONTRACT AND CONTRACT DATA - SBC

Figure 13



5.6 Relations Client-Engineer-Contractor. In this project with its very high site costs resulting from and consisting of expensive specially made heavy equipment, prefab factory, trained contracted personnel and with a large continuous flow of world wide imported high quality bulk materials, the importance of keeping the production running without disturbances can not be over emphasised. This could only be achieved by establishing and monitoring the routines and operations and a secured follow up by the contracting parties.

It goes without saying that those mega projects in developing countries nevertheless always create unforeseen incidents or events which will require solutions dependent upon positive and flexible well integrated teamwork based on mutual trust between the Client, Engineer and contractor.

Conclusions to Theme B Engineering and Construction Management

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1. SUBJECT

The owner or client who is undertaking a project is interested in getting the best overall result. This is not a simple task to-day regarding all the factors that should be taken into account and the many disciplines and relationships involved in a construction project.

Project management is the way to manage undertakings that are limited in scope and time as an entire task. Complex situations can be simplified and better controlled by defining projects and by managing them professionally. Project directives containing the essential information about the whole project in a short document and project handbooks as a more extensive documentation help to find and to maintain a common policy.

Since the first presentations on a similar topic at the IABSE Congress in Vienna (1), engineering and construction project management became a more and more consistent science, and a necessity for competitiveness in many marketplaces of the world. At the Vancouver Congress, contributions about the application of management principles to very prominent projects from Japan, South America, China, Canada, South-East Asia, and the Near East were described.

Quite large projects telling the lessons of single projects that involve large risks and benefits were selected. However, project management is applicable to a much wider range of projects. There are lots of medium- and large-scale construction projects, and even in a large project, there are many subprojects. Indeed, each consultant, contractor, supplier, and subcontractor manages a project of his own.

2. SYSTEMATIC PROJECT MANAGEMENT

The problems of project management are to define and to reach the project objectives, to know the actual status at all times, and to know the ways and means to achieve the next intermediate targets. This means to maintain the control in the following theoretically known areas during all phases of the project cycle:

- the operations that should be performed in the constructed facility when in operation, and their best possible benefit-cost-ratio as the general project objective
- the technical concept, dimensions, and quality of the constructed facility and all its subsystems and components
- the time schedules on several levels and in all important disciplines, with an economical resource usage
- the cost accounts on several levels and in all important disciplines, as related to the life-cycle costs and benefits of the facility
- the positions of the project organization and their work tasks, skills, motivations, responsibilities and rewards as well as the procedures of communication in this organization
- the environment of the project and its possible changes during the project cycle and during the constructed facility's life cycle.

The technical system can be considered as the basic reference system for all these areas of control (2).

Both the theoretical and the phenomenological approaches are worthwile for investigation. The theory tries to generally answer the questions of the future. However, it is important to observe as well the up-coming needs, problems and opportunities of the future, the kind of relevant questions arising, and the type of projects that will have to be managed most frequently.

3. KNOWLEDGE PRESENTED

Each participant of the congress and each reader of the preliminary (3) and this final report may put his emphasis on different methods and experiences presented on that occasion. Here, a few points are summarized from a personal point of view.

The view into a longer-range future shows the potential of renovation projects and especially the great potential of new construction projects in the urban areas of developing countries. - When organizing a project, not only the functions of the consultants and contractors, but also the tasks and responsibilities of the owner and the operations planning should be considered. It would be interesting to know the criteria for an optimal allocation of tasks to the parties involved. - Quality management is a sometimes underestimated part of project management. Project time scheduling, cost planning and control, and project organization need a general technical background, if a real coordination shall be provided. - Construction projects can be designed and realized with an estonishing speed to-day. The large differences of duration for similar projects could be an indication of deviating objectives or construction technologies. - Thinking in terms of systems is considered as an essential basis of project management. Both the break-down of the entire system to subsystems and components fulfilling defined work tasks, as well as the communication and material flows taking place within the systems are open to discussion. - Large and complex projects can be controlled, but the corresponding management effort is quite often underestimated. Project management should reduce the risk of the organization undertaking the project which can be done by reducing the probability of occurance and by reducing the amount of the possible damage.

4. PROBLEMS FOR THE FUTURE

Engineering and construction management is quite a young discipline. Although several reliable conceptual models could be found in the past two decades, many parts of the field are not yet explored deep enough to be ready for detailed explanation, computer programming, and instruction.

Professional project management is more and more widely used, but many fields are still open for beneficial application and improvement. Decades of teaching, exchange of experience and research activities will be necessary for this achievement on all levels.

The theoretical connections between the management science and the engineering and construction sciences are not yet well enough established, although the progress made in the last decade is remarkable. Indeed, project management is very close to construction practice, at least as close as corporate or product management.

It took many decades and an enormeous scientific effort to find an accepted terminology in structural analysis. A similar statement will probably hold for each project management area.

REFERENCES

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(3) IABSE Congress, Vancouver, 1984, Preliminary Report, pp. 13-24