

PROCEDURES AND ORGANISATION
IN THE BUILDING INDUSTRY

A report submitted in partial fulfilment of the requirements for the degree of Master of Engineering at the University of Canterbury, Christchurch, New Zealand.

by

W.G.Braine

February 1972

ABSTRACT

This report examines the concept of a co-ordinated team of developer, architect, engineer and management contractor whose sole interest is that of the client. Such a unit could overcome most of the traditional problems which demonstrate the building industry's lack of control, lack of teamwork, lack of understanding and unnecessary complexity.

Productivity, cost control in design, prefabrication of materials and organisation of site labour are some of the important topics discussed from the point of view of a central management unit.

ACKNOWLEDGEMENTS

The author wishes to express his thanks and appreciation to Mr. A.G.Fellows whose many years of experience in control of consulting engineering projects offered valuable guidance and interesting discussions.

Mr. O.T.Jones, Chief Estimator M.O.W., kindly made his time available for early discussions on problems and procedures in the building industry.

TABLE OF CONTENTS

<u>Chapter.</u>	<u>Page.</u>
Abstract	ii
Acknowledgements	iii
Table of Contents	iv
1. Introduction	1
2. Management	6
Organisation	8
Leadership	10
Management by objectives and self control	13
3. Measuring Performance	16
Profit	16
Productivity	17
Value Engineering	19
4. Cost Control in Building Design	21
Inadequacies of Traditional Costing	23
The Techniques of Cost Control	25
Feasibility Stage	25
Outline Design Stage	27
Scheme Design Stage	30
Detail Design Stage	34

<u>Chapter.</u>	<u>Page.</u>
5. Costs-In-Use	38
Cost of Glazing	39
Cost of Capital	40
6. Contracts	41
Management Contracts	41
Separate Contracts	42
Design and Build Contracts	44
7. Prefabrication Concept	46
8. Subcontractors	49
Organising Site Labour	49
Cost Proportions	50
Management of Subcontractors	51
Serial Contracting	53
9. Summary and Conclusion	54
References	56

CHAPTER 1.

INTRODUCTION

This report examines the nature of problems in the building industry and discusses how they may be overcome. After considerable business and engineering study plus some practical involvement the author became aware of many interrelated problems and inefficiencies associated with all stages of the building function, including weak overall management, uncontrolled design, unnecessary barriers created by the open tendering practice, and poor organisation of building erection. An appreciation of the building industry's shortcomings may be gained from the following general examples.

Firstly, developers need to know the maximum cost or cost limit of a building project at the feasibility stage. Yet design consultants traditionally do not employ effective cost control methods to control the development of a design concept within the agreed capital cost estimate. Hence cost limits tend to be haphazardly exceeded, expenditure between the various parts of the building is unbalanced and poor value for money results.

The practice of open tendering plus the employment of independent consulting specialists have forced the building industry into a complex fragmented system in which cost control information is not permitted to flow for the mutual benefit of the industry as a whole. In no other important industry is the

responsibility for design so far removed from the responsibility for production. Even when considering the production function on its own, few contractors have adequate feedback arrangements for site experience to affect estimating, and in most firms the management of contracts works in ignorance of the thinking that has gone into estimating. (Bishop 1969).

The building industry deals in large unique products and as such should be organised into homogeneous stages. However, the industry is mainly trade organised, with planners and managers perhaps ignorant of the benefits to be achieved by reorganisation. After the Second World War an attempt was made to introduce prefabricated, standardised parts into house building. The use of prefabricated parts in a trade system proved more expensive and slower than the old methods. When, however, the Levitts in Long Island organised home building by homogeneous stages, they could immediately use uniform standardised prefabricated parts with conspicuous savings in time and money. (Above example given by Drucker 1968). A high degree of prefabrication, especially in multistorey buildings, is now common place, yet many building sites are still trade organised.

The above problems indicate the building industry's lack of control, lack of teamwork, lack of understanding and unnecessary complexity. Most of these problems are a result of poor organisation and management. Production is not the application

of tools to materials; it is the application of logic to work. An economic lesson can be learnt from the small clay brick which is still competitive because of its simplicity and repetition.

The present system, including the design function, must change and in moving from one system to another we must learn how to do new things, rather than learn to do old things better. We must learn how to control costs during design, and we must learn to work with and understand the people in a single team of developer, architect, engineer, quantity surveyor and construction manager. The present freedom of architects and engineers must be tempered to teamwork because they do not have the education or information to control and manage the building industry when acting as individuals. Designers and planners must learn to apply the concept of increased productivity and how to make decisions from an improved flow of information, so that architects and engineers do not only concentrate on minimising materials but rather minimising overall costs.

A recent example of overall teamwork at the conceptual design stage was a \$3 million precast concrete multi-storey parking building project, which was successfully completed for the Auckland City Council. The overall construction time of nine months was achieved without overtaxing the building industry and the adjusted capital cost per car was 5 percent less than four existing parking buildings in Auckland. The success in meeting

the client's requirements which were completion on time and to a guaranteed price, was due to the liaison between architect, engineer, developer-contractor and the precast industry at the conceptual design stage. This example might be used to support design - and - build contracts. However, there have been many failures with these because the co-ordinated team does not have the sole interest of the client during construction.

An increasing range of prefabricated standardised building components which can be rapidly assembled on site, plus very efficient specialised teams of subcontractors are reducing the prime contractor's role to that of a co-ordinator. This trend means that the prime contractor could completely subcontract construction and become part of a single team which offers design and management services.

This report examines the concept of a co-ordinated team of developer, architect, engineer and management contractor whose sole interest is that of the client. Such a unit could overcome most problems in the building industry by combining the skills and common understanding of construction, administration, engineering and architecture. The overall arrangement of the building industry could be expressed as "federal decentralisation with co-ordinated control". Each production or assembly unit must have the ability to stand alone and not rely on other units for favourable concessions. These units are co-ordinated by a

central management unit which is market orientated to satisfy its client's needs. To achieve this, the central co-ordinated team must generate a guiding force to co-ordinate, direct and focus its energies towards the achievement of its objectives, namely the completion of a well executed building project on time, and within a cost limit or to a guaranteed price.

CHAPTER 2.MANAGEMENT

Change dominates the world of today. The environment in which business operates is dynamic, and the manager should be always alert to adapt the operations of his company to the opportunities and challenges which these changes create. To survive these changes there is a continual need for forecasting, planning, organising, co-ordinating, communicating and controlling. In a competitive economy, above all, the quality and performance of the managers determine the success of a business, indeed they determine its survival. For this reason management is a practice, rather than a science or a profession, though it contains elements of both. (Drucker, 1968)

One of the biggest changes facing the building industry at present is the increasing awareness for efficient overall organisation and co-ordination, using the latest scientific management techniques. Two eminent engineers, Ove Arup of Britain and Peter Corradi of the United States, who have both had varied careers within the building industry, are firmly committed to the proposition that traditional relationships between owner, designer and contractor should change. (Arup, 1968 ; Corradi, 1971)

Ove Arup reports considerable interest and activity towards multi-disciplinary group practices, but that barriers which are astoundingly solid and high must be broken down. All the members

have to forget part of their training and acquire new understanding and skills. Arup also reports the reaction of architects, contractors and quantity surveyors, each claiming leadership of the multi-disciplinary building team.

Actually, the need for re-organisation, better communications, strong leadership and a common understanding between specialised personnel has been realised for some time, but a very strong force has prevented change. Arup explains this force as harmful, and originates from members of learned societies and institutions who cherish their particular authority and are jealous of outside interference. This behaviour breeds narrow-mindedness and hinders the effective use of resources. Thus major change may continue to be resisted until serious competition is exerted by multi-disciplinary teams that can act with a common understanding and respect.

Communication barriers sometimes rise to frightening heights under the traditional organisation system. An example was given by the Royal Commission in its report (Royal Commission 1971) on the failure of West Gate Bridge in Melbourne, Australia in 1970. The firms and companies involved were all of the highest reputation, well established and had demonstrated their ability by the successful undertaking of important projects. Yet astonishing confusion, lack of co-operation and antagonism developed.

On this project, all parties attempting to communicate with the engineering designer experienced the greatest difficulty in obtaining replies to their communications, which were rarely answered promptly, frequently answered after interminable delays and repeated reminders, and often not answered at all. This practice provided excuse for delays by the contractor and doubtless had a bad effect on the morale of the contractor's staff. A more serious aspect was that the required information on some very important matters was deliberately withheld. The refusal of the designer to supply the contractor with data which had been promised, gravely disrupted the contractor's programme and initiated the friction that developed between the two organisations.

After further developments and changes the responsibilities and authority of all parties became poorly defined. This led to confusion and unusual behaviour of senior site personnel that was disastrous, as it created the circumstances for actions which were the immediate cause of the failure and collapse of a 367 ft bridge span, with the deaths of 35 men.

Organisation:

Personnel within the building industry are extremely dynamic and flexible, yet methods and procedures have changed little during the last century compared with other major industries.

This is a result of poor overall organisation and that the various sections of the industry have long acted independently. It is a fact that specialisation plays an important part in achieving economies, but only when all specialists are co-ordinated to think and act as a whole will the true economies of specialisation be realised.

It is important that designers and planners work together to organise site operations so that each specialised site team can work within a homogeneous stage. For example, the insitu concrete service tower of a multi-storey building is often designed to give structural support and stability, and act as the central fire protected access to all floors. This can be constructed using slip forming. This technique was used to construct the 556 ft. service tower in five weeks for a 40 storey building in Baltimore, United States. It involved the continuous pouring of concrete into a slip-form which rises steadily, one inch (2.5 cm) every five minutes, 24 hours a day, five days a week. The slip-form unit gave protection from weather and a guaranteed rate of progress. This homogeneous stage was followed by the erection of prefabricated units around the service tower. This type of homogeneous stage organisation has been too often neglected by designers in the past.

The organisation within a team of specialists should always be such to encourage strong effective leadership so that the team

can efficiently act as a whole. Team members belonging to different societies, institutions or unions tend to hinder the working unity of the team and their individual needs must be co-ordinated with considerable skill.

Leadership:

Leadership can only effectively operate long-term when it meets or brings together the needs of both the enterprise and its people. Careful and thoughtful acceptance of each individual must precede his becoming a group member. Given these conditions the wise leader can release immense creativity from average people to the benefit both of the individual and of the enterprise. Such leadership gives very deep satisfaction to the leader himself.

Leadership is a natural gift, which not everyone possesses. Some people seem to be born with the necessary attributes of leadership, whereas others simply are not so inclined. But there is no reason why the average manager cannot become a reasonably skilful leader by means of personal discipline and effort. The following are those leadership qualities that the manager should strive to develop in order to exercise most effectively his designated authority: (Clough, 1960)

1. Be fair and impartial. This should apply to one's relationships with all his business associates, including

those who are in no position to offer strenuous objection to the actions of management. A reputation for fairness and impartiality will command respect and trust.

2. Be loyal. Few human virtues are more admired than steadfast loyalty. This must apply to one's subordinates as well as to one's superiors.
3. Be honest. Admit your own mistakes. Be straightforward and direct in your dealings. Always give credit where credit is due.
4. Be dynamic and aggressive. Nothing sets a better example than the manager who is genuinely enthusiastic about his work and vigorously pursues his assigned duties. Enthusiasm is contagious.
5. Be quick to praise and slow to condemn. People respond to praise in a remarkable way and will redouble their efforts to please after a little encouragement. An unwarranted rebuff can very effectively destroy personal initiative. Be tolerant of other people's mistakes. However, the manager must act decisively when disciplinary measures are called for.
6. Have the courage of your convictions. Considerable fortitude is sometimes required to defend an unpopular opinion. The manager should persist in his conviction until such time as he becomes convinced that he should

alter his position. A sharp distinction, however, must be recognised between an honest belief and mulish obstinacy.

7. Be consistent. The executive must exhibit a reasonable consistency of outlook to be dependable. Undue wavering on the part of management will breed confusion and hesitancy within the ranks of the organisation.
8. Have faith in your job and your company. Half-hearted or insincere management efforts are strikingly obvious to the rank and file and play havoc with their morale.
9. Be tactful. Many business dealings involve matters of a delicate or touchy nature. Unpleasant subjects are best handled when they are squarely faced. However, tact can help resolve such matters with a minimum of personal offense and resentment.
10. Be courteous and considerate. This involves nothing more than a genuine regard for the feelings of others. It can be of great assistance in eliciting friendly co-operation rather than indifference or hostility.
11. Have a working knowledge of human psychology. This calls for a sympathetic insight into human behaviour. Many problems brought to the manager by his personnel may appear petty and inconsequential. However, they are very likely of extreme importance to the individual

involved and must be so considered by the manager.

12. Be technically competent in your job. The manager must be technically competent in the phase of the work that he supervises in order to oversee properly those activities for which he is responsible. He must be conversant with the literature in his field and keep abreast of the latest developments.

13. Guide and direct rather than command. Most people seem possessed of an ingrained resentment at being told to do something. In the majority of cases, the manager can transmit his orders in a more acceptable manner than as a blunt command.

14. Be a good listener. Surprisingly enough, most aggressive leaders are also good listeners. There is much to be learned by just listening, and subordinates usually appreciate a superior who will listen sympathetically to their troubles.

Management by Objectives and Self-Control:

The greatest advantage of management by objectives is perhaps that it makes it possible for a manager to control his own performance. Self-control means stronger motivation: a desire to do the best rather than just enough to get by. It means higher performance goals and broader vision. Even if management by objectives were not necessary to give the enterprise the unity of

direction and effort of a management team, it would be necessary to make possible management by self-control. (Drucker, 1968)

There is bound to be an increase in the number of highly educated specialists, but there must also be much closer co-ordination between specialists. The need is for all specialists to see the business as a whole and have a clear understanding of its objectives.

Architects and engineers for some time have used quantity surveyors to produce information to base decisions and to estimate cost. Unfortunately the quantity surveyor conventionally calculates cost by multiplying quantity of material by a single cost rate. This means that designers only concentrate on minimising materials and not overall construction costs. This simple measurement even tempts designers to reduce materials at the expense of complexity.

There is a need to measure design performance with much broader vision to achieve higher performance of the building industry as a whole. Quantity surveyors must work closer to designers throughout the design stage and they must learn to give a much better service than that based on single rate estimation. They must be able to supply productivity information. That is, the designer should know the productivity rate of placing materials under a certain construction method and site arrangement, so that the design is the most efficient. This will also enable the designers to produce a basic construction plan and critical path

to give construction managers a clear picture of the proposed project.

CHAPTER 3.MEASURING PERFORMANCEProfit:

Profit is often referred to as the prime objective of a business. Then the question must be, why is not profit the single measurement to base decision making. It was stated by the President of the N.Z. Society of Accountants, R.W.Steele, in the N.Z. Institution of Engineers journal (Steele,1971), that all managements must face the fact that ;

1. If profit is the prime objective, and
2. If profit can only be measured by accountants, and
3. If only accountants have the expertise to interpret financial information with a clear understanding of the reservations which apply to that information, then accountants will continue to dominate all business decisions.

Profit can not be used by an agent to a client because he is paid a fee which is a fixed percentage of the total cost. On this basis profit is only a measure of how little time was spent on a project as time is the agent's major scarce resource. Also efforts to reduce total cost will only reduce an agent's profit for that project. A client and his agent both need a basis to measure performance and judge decisions. Also we are concerned with the total performance of the building industry and its

efficiency in satisfying the needs of society. Profit is a reasonable measure for a management contract which offers a "package deal" at a guaranteed price, or for subcontractors working under a lump sum contract. However, profit where applicable is only the result of a business. Far more important is the reason for profit and how it can be maintained. Profit can only be maintained if a business is competitive, therefore in measuring performance and making decisions we are interested in the ability to be competitive now and in the changing future.

Productivity:

Productivity is an attempt to measure the skill with which resources are used to satisfy the needs of society and as such may be used to measure the ability to be competitive. Productivity is often referred to as the ratio of input to output. The inputs basically consist of land, materials, machine time and labour. The outputs are the products that determine our standard of living. A higher productivity means more is produced with the same expenditure of resources, or the same amount is produced with a lesser expenditure of resources, thus releasing some of these resources for the production of other things. A striking example of increased productivity was the Industrial Revolution using new machinery and mass production methods.

An immediate problem arises in quantifying both input and

output in suitable units, as productivity is a balance between a great variety of factors, few of which are clearly definable or clearly measurable. The largest changes in productivity have been due to savings in the labour input by using improved methods, tools and machinery. Also labour holds a central place in the economic system since it is both producer and consumer. For this reason the average production per worker has special significance as an index of productivity. For example, if a worker produces 40 units per hour and improved methods of work enable him to produce 50 units per hour then the productivity of that worker has increased by 25 percent. However, if more expensive tools and machinery are involved it is incorrect to claim a 25 percent increase in the skill of using resources.

Both input and output could be considered in money terms; so how much was spent on manpower, how much on materials, how much on capital equipment, etc., could be tabulated under input. The output considered in money terms is the price the product will fetch on the market. This is a simple matter if the product, in this case a building, is constructed and sold by a developer with the difference between input and output as the developer's profit. However, as mentioned earlier the problem is to measure the ability of an agent in producing efficient design and management services. Most buildings can be expressed in terms of a return on investment. Flats, office blocks, warehouses and even shops can

be given a rental value. Using an acceptable interest rate the "present value" or selling price may be determined. The ratio between total input expenditure and calculated selling price is the productivity or a measure of the skill with which resources were used. In achieving the highest possible productivity the client or owner must receive the best value for money.

Value Engineering:

Value is a difficult term to define. It is not synonymous with cost, as costly materials may be used to assemble something of little value. Value engineering is a technique that directly affects productivity as it sets about achieving the required function of the output using cheaper input resources.

The most obvious point at which to control the cost of a building is at its conception; the design stage. By using the most economical materials, and a configuration which lends itself to the most effective methods of production and simplest methods of assembly, the designer can ensure that costs will be reduced to a minimum. This is the objective of value engineering. It is essential, therefore, that designers should be cost conscious as well as function conscious. For example (Anon.,1968b), it is still a distressingly common practice to provide heavy and expensive walling to boiler houses when only a light cladding may be necessary.

Still another way of measuring the performance of a design and management agent, and improving productivity is to decide a cost limit based on the function of the building. This cost limit is calculated from cost records of previous successful projects and acts as a reference throughout design and planning to measure possible improvements. This method of cost control during design is explained in detail in Chapter 4.

CHAPTER 4.COST CONTROL IN BUILDING DESIGN

This chapter is covered in considerable detail because the author feels such a technique will bring together architects, engineers and quantity surveyors with desirable results towards the understanding, respect and co-ordination which is seriously lacking in the traditional design function.

Cost is used as a means of measurement, and it must be controlled to give the client value for money. The value of a building to a client depends on how well the elements do the things which he wants them to do rather than on the intrinsic value of the labour and materials used for their construction.

The main purpose of cost control is to keep expenditure within the amount allowed by the client which should be confirmed at the end of the feasibility stage in the form of a cost limit. In achieving this purpose, however, cost control can give the client good value for money and achieves the required balance of expenditure between the various parts of the building.

An example of an experienced client insisting on the use of a cost limit was demonstrated in 1966 by a United Kingdom government agency, the Medical Research Council. The client initially prepared a brief stating the priorities as quoted.

1. construction of a building within the cost limit agreed by the council;
2. provision of a building to meet functional needs of the

unit as expressed in the brief;

3. the building to be completed on time;
4. aesthetic effect of the building externally and internally.

At the first meeting with the design team it was stated that no alteration to the cost limit would be contemplated after the feasibility stage, the only exception to this being changes in the client's brief. The design proceedings for this example are well documented in the "Architects' Journal" (Anon., 1968a)

Control is a management function and associated decisions should be made at the lowest possible level but also at a level ensuring that all activities and objectives affected are fully considered. This means the design team must learn to control the costs created during design. The principles of control are; there must be a frame of reference, a method of checking, and a means of remedial action. These three principles are applied in a repeated cyclic manner. To achieve the objective of cost control the frame of reference must be established from a realistic first estimate and deciding how this estimate should be spent among the elements of the building.

The principles of control are becoming well known in many forms of management techniques. Probably the best known to the building industry is the Critical Path Method and the way it is used and updated to control construction progress.

Throughout this chapter continual reference is made to the "Research and Development Building Management Handbook, 4; Cost Control in Building Design HMSO" (Anon., 1968b)

Inadequacies of Traditional Costing:

Traditional estimating techniques originated in mid victorian times to help the builder calculate his tender for a building. His method of approximate quantities stems from the builder being solely concerned with the price of labour and materials, and not with function or use of a building. Quantity surveyors have simply used builders' methods.

When it was necessary to give the client an estimate before detailed drawings and specifications were available, a method of single rate estimating, such as cubing, evolved. This method, to be effective, must be used to compare costs per unit area of a building of similar type, construction and finishes, built on similar sites under similar conditions.

Both these methods were sufficiently accurate when first applied because there was less complex use of buildings, lower standards of comfort, fewer amenities, little or no state control of buildings and a small range of building materials. However four pressures encouraging change include; the client's requirements are more complicated, the client organisations are larger, the pace of development in building is increasing, and the many new construction methods and materials available. For these reasons the technique

used for cost estimation is no longer sufficient, and a technique is required to control costs during design.

Again, the main purpose of cost control must be to keep the design concept and details within the cost limit allowed by the client. If a professional consultant is not prepared to stand by the estimate given at the end of a feasibility study then the client will not be impressed and will look for a concern that is more capable. After all, that is the meaning of feasibility and the client must know the cost to be able to make the decision to proceed or abandon the project at the end of the feasibility study.

The Techniques of Cost Control:

It is important to remember the following principles of cost control.

1. There must be a frame of reference, establishing a realistic first estimate and planning how the estimate should be split up among the elements.
2. There must be a method of checking or feed-back.
3. There must be a means of remedial action.

The remainder of this chapter involves a detailed description of the steps taken at each stage of design.

Feasibility Stage:

To provide the client with an appraisal and recommendation, in order that he may determine the form in which the project is to proceed, ensuring that it is feasible functionally, technically and financially (R.I.B.A. Handbook)

The most important thing at this stage is to assemble a range of costs for the particular building type required. This can be done by referring to cost analyses contained in office records, or published by the technical press, or in England cost studies published by the Building Cost Information Service (B.C.I.S.) etc.

The information available at the feasibility stage is usually limited to; space, use, quality, and site. The cost decisions made at this stage are based on the client's functional requirements

rather than on a particular design solution.

Preparation of the first estimate is by a method of interpolation. The steps consist of:

1. A range of cost analyses of the same type of building as the proposed building is assembled.
2. This range is examined to find the cost analysis of the building whose quality approximates most closely to that desired by the client.
3. The initial brief of the proposed building and all of the information given in the cost analysis are studied in order to isolate the major differences between the two buildings.
4. Allowances are made for each of these major differences (including differences in floor area and general market price level)
5. Finally, an allowance is made as a reserve against price rises between the general market price level at the date of preparation of the first estimate and the contractor's price level on the tender. This allowance should also include a figure to cover design risk by assessing the cost of unforeseen design difficulties.

When the first estimate has been completed, it is put to the client as part of the design team's report on the feasibility of the project as a whole. If the client accepts this first estimate,

it becomes the cost limit for the project from then on. However, in certain projects where the brief is not sufficiently developed or due to technical difficulties, it may be necessary to state a range of costs, leaving the preparation of the firm cost limit until the completion of outline designs.

Another approach to determining the cost limit may be as follows. A developer estimates the rent forthcoming from a building of given quality and size over its potential life. He then deducts operating and maintenance charges for this potential life, and the balance, when capitalised at an acceptable rate of interest, represents the sum available for construction, professional fees to the design team, and for the developer's profit. The balance then represents the absolute cost limit. If this sum is exceeded in the estimate, the project may not be pursued.

Outline Design Stage:

To determine general approach to layout, design and construction; in order to obtain authoritative approval of the client on the outline proposal and accompanying report. (R.I.B.A. Handbook)

At this stage cost targets are prepared for each major group of elements. An example of these major groups would be substructure, superstructure, internal finishes, fittings, services and external works.

The information available at the beginning of the outline

proposal is

1. the design criteria;
2. the general brief;
3. the town planning policy; and
4. the feasibility report (including the first estimate,
which has been approved by the client by this time)

Cost planning is performed in stages of increasing detail and availability of information, working from the general to the particular, so that the client and designer are fully aware of their involvement and are able to control development with the minimum of abortive work. Within each stage there is a relationship between available information and the design and cost decisions as shown in figure 1.

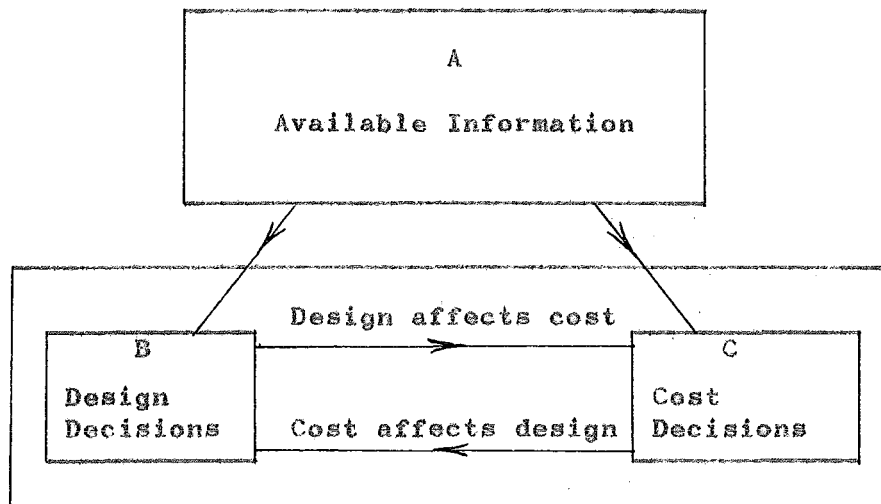


Figure 1.

In preparing the cost target for a group of elements the first step is to isolate the differences. This is done by comparing the

specification of the elements in the analysis with what is known about them in the new project. The major differences are allowed for by comparing all information available for both buildings. These differences can be allowed for by interpolation as in the feasibility stage or by using, with less detail, the methods that will be described during the Scheme Design stage. As in the Feasibility stage an allowance is made for 'Price and Design Risk'.

If there is a major discrepancy between the outline cost plan and the cost limit, it is best for the client and the design team to make a joint decision as to whether it is better to juggle with the allowances or to accept that the outline cost plan total is more realistic than the first estimate. If this results in the cost limit being raised rather than lowered, at least the client has the opportunity of abandoning the project before incurring major expenditure.

The above theme applies to each stage of design development and the design specialists should avoid moving into a new stage of work before completion of the previous stage. These points must be carried throughout the chapter and will not be repeated.

Examples of uncontrolled soaring costs are unfortunately common. In 1956 the U.S. Naval "Big Dish" radio telescope project was approved on a budget of \$20 million. By the end of 1957 feasibility studies reported a cost of \$52.2 million for pure scientific work.

The decision was made to combine military functions at a total of \$79 million. These cost estimates were subsequently changed to \$126 million and then to over \$200 million. In 1961 some years after construction had begun and with designs still not fully crystallized, Congress set a ceiling of \$135 million on the project. In 1962 with expenditures of \$63 million and a number of contractors' claims for other payments, work was stopped and the project was abandoned. This was because design work still being completed for the superstructure showed steel of twice the estimated weight to be supported on already constructed foundations. Also the original estimate of 30 persons to man the instrument had been increased to 1,146 persons. (Feld, 1968)

Scheme Design Stage:

To complete the brief and decide on particular proposals, including planning arrangement, appearance, constructional method, outline specification and cost, and to obtain all approvals.

(R.I.B.A. Handbook)

At the Scheme Design stage a cost target is prepared for each element. This element-by-element allocation of costs forms the detailed cost plan. The total cost of the building and the cost of each element is expressed as cost per sq. ft. of total floor area. This cost plan is simply a statement of how the design team proposes to distribute the available money on the elements of the building and incorporates the first principle of cost control;

that is, there must be a frame of reference. Some of these elements can be listed as :

1. Work below lowest floor finish
 2. Frame
 3. Upper floors
 4. Roof
 5. Staircases
 6. External walls
 7. Windows
- etc.

The information available when the cost plan is started is :

1. the complete brief;
2. the outline design (including drawings);
3. the outline cost plan; and
4. all the information available at the beginning of Outline Proposals.

Before considering each element individually, an allowance is made for the Price and Design Risk which will usually be slightly less at this stage than at the Outline Proposals.

The factors affecting element costs are :

1. Quantity;
2. Quality; and
3. Price Level.

The differences in Quantity and Quality will depend on the client and designer. The differences in Price Level can be attributed to the following factors.

1. difference in general market price level;
2. variation between the contractor's price level and general market price level at tender date;
3. difference in site conditions and location; and
4. difference in Contract Conditions, weather conditions, etc.

A price level index can be used to factorise the difference between the tender date of the analysed building and the present stage of the proposed building. Any difference in cost between the present stage and tender date of the proposed building, plus variations between the contractor's price level at tender date, and finally unforeseen variations in other Price Level factors are allowed for in the Price and Design Risk. Variations in site conditions and Contract Conditions which are obvious at this stage are allowed for in Preliminaries.

The methods that can be used to prepare cost targets are :

1. Simple Proportion;
2. Inspection; and
3. Approximate Quantities.

Simple Proportion is preferred to the other two methods because a simple proportionate adjustment to an element cost in a cost analysis automatically includes allowances for everything one needs for the element in the particular type of building considered.

When using Approximate Quantities on the other hand, it is easy to overlook details which will only be considered during the Detail Design stage. Nevertheless, this method sometimes has to be used, especially when a new requirement is under consideration.

Inspection is usually reserved for elements such as ironmongery for which no effective measure of quantity has, as yet, been devised.

An Example of Simple Proportion

Element 4 : Roof

There is no major differences between analysed building and proposed so Simple Proportion can be used.

Adjust for Price:

Element unit rate from analysis = \$1.55 per sq.ft.

∴ Current element unit rate

$$= 1.55 \times \frac{152 \text{ (current price index)}}{131 \text{ (analysis price index)}} = \$1.80 \text{ per sq.ft.}$$

Adjust for Quantity:

Quantity (from drawings) = 8,000 sq.ft.

∴ Total element cost

$$= 8,000 \times \$1.80 = \$14,400$$

Reduce to cost per sq.ft. of total floor area (4 floors)

$$\frac{\$14,400}{32,000} = \$0.44 \text{ per sq.ft.}$$

Adjust for Quality:

The spans and loadings are nearly the same in the analysed building and proposed project. In addition, the standard of insulation and

the quality of waterproof material are adequate for our purposes, so it is decided that no adjustment for Quality is called for.

COST TARGET	Total	Cost per sq.ft.
FOR ROOF	\$14,400	\$0.44

Detail Design Stage:

To obtain final decisions in every matter related to design specifications and construction, and cost of any part or component of the building (R.I.B.A. Handbook)

The Detail Design stage is the crucial stage in controlling the cost of the detailed design. During the Detailed Design stage there must be a method of checking and there must be a means of remedial action. The basic cycle of operations is:

1. Design.
2. Approximate Quantities estimate.
3. Comparison with Cost Target.
4. Decision and action.

This cycle of operations is repeated until all the elements have been designed and cost checked.

The Approximate Quantities method is generally accepted as the best method when based on detailed design and specifications. However, a more accurate method, if compiled by a technically competent and experienced person, is by considering the required resource and productivity rate. This method combines planning the

job, time requirements and resource requirements with cost estimating. The direct cost is the sum of resources needed multiplied by price of resource.

Resource	Productivity	Resource
	Rate	Price
Steelfixer	0.3 ton/hr	\$1.50 /hr
Steel	0.95 ton/ton	\$180 /ton
Paint	500 sq.ft./gal	\$10 /gal

If the cost of the element designed is sufficiently close to the cost target then the action is to confirm that design is suitable for working drawings. If the designed element cost is greater than the cost target then the two possible courses of remedial action are :

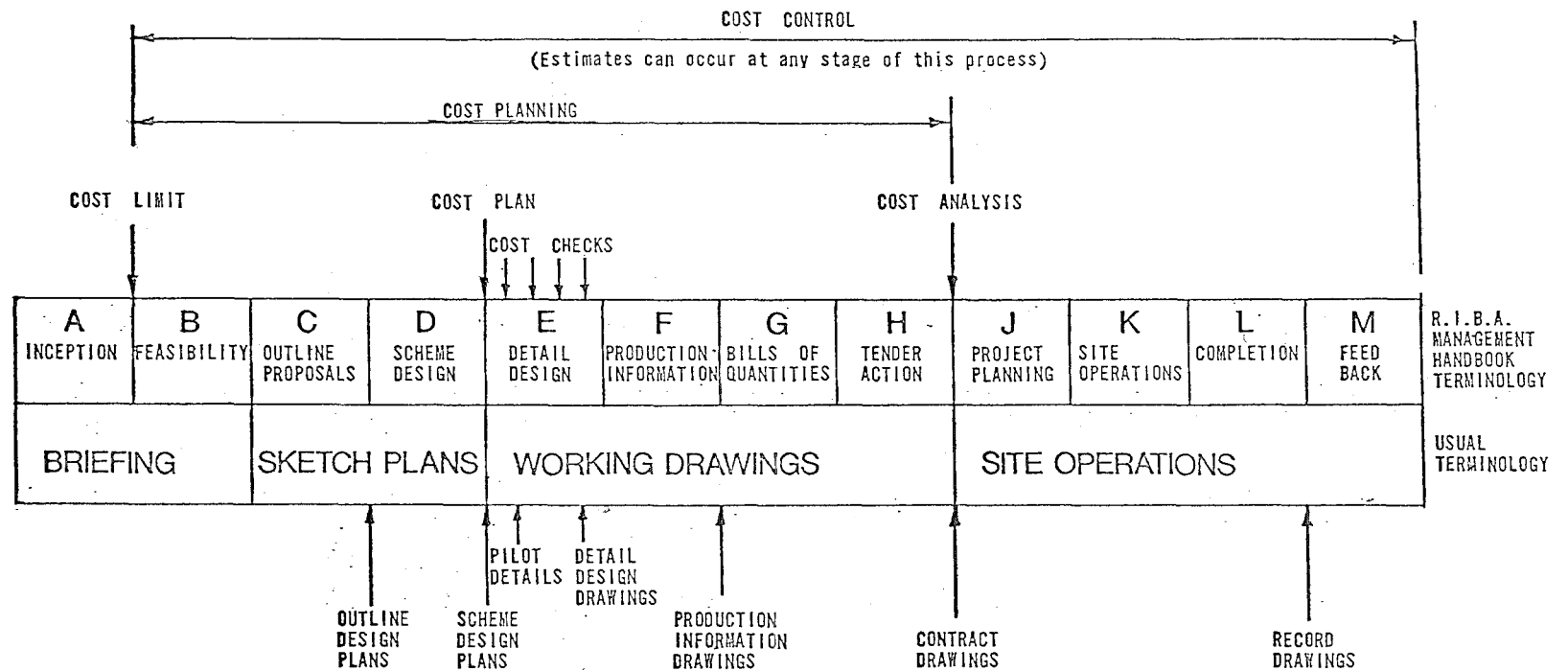
1. the design of the element can be altered in an attempt to bring its cost within the cost target.
2. as a last resort, the cost target for the element can be raised.

If the second action is taken, cost targets should be adjusted throughout the cost plan to release surplus funds for the element in trouble. The disadvantage of this action is that the pre-determined balance of expenditure is changed and careful consideration will have to be given to good value for money.

To reduce possible abortive design work the elements should be designed in a reasonable order. Consideration should first be given to possible unreliable cost targets, large cost targets, and

to a design which affects the design of other elements. Thus a programme of detailed design should be prepared. If several elements are designed concurrently, they should all be cost checked several times during their design.

DESIGN PROCESS TERMINOLOGY



This page is reproduced from the Research and Development Building Management Handbook 4 "Cost Control in Building Design" (Anon., 1968b)

CHAPTER 5.

COSTS - IN - USE

The previous chapter considers how the right balance between appearance, function and capital cost may be controlled. For a design to achieve good value for money the life time performance and hence the costs of maintenance, heating, lighting and other services must also be considered. Often the running costs of a building are three times as great as the initial capital costs (Stone, 1967). Of course, the running costs are spread over the life of a building and it would be meaningless to add up the face values. The initial and future running costs need to be reduced to equivalence by adjusting for rate of interest and inflation over the time period. All costs are converted to their "present worth" or in terms of their "annual equivalent costs."

Calculated Example: Present Worth.

Capital cost = \$100,000
 Total running cost = \$300,000 over say
 60 years.

i.e. = \$5,000 per year

Interest rate = 9% per year

Inflation rate = 3% per year

To bring the annual running cost to present worth it must be multiplied by a uniform series present worth factor. In this case

the factor from discount tables is 16.16.

$$\begin{aligned}\therefore \text{Present worth} &= \$100,000 + \$5,000 \times 16.16 \\ &= \$100,000 + \$80,800\end{aligned}$$

$$\text{ie capital : running} = \$100,000 : \$80,800$$

Hence the running costs are usually less than the capital costs of a building (Stone, 1967). The theoretical basis of discount calculations will be found in texts on engineering economics, (e.g. Lu, 1969).

Cost of Glazing:

Glazing provides an example of effect of design on Costs-in-use. Glazing is usually more expensive to install, maintain and to clean than the wall cladding it replaces. Moreover, heat losses through glass are greater than through most other cladding materials. Economically the use of glass has to be justified in terms of the saving in lighting costs and in its aesthetic and amenity value.

The value of glass in admitting light varies with its position and with the use of the building in which the glass is used. The light admitted by glass, at or near the floor is of little value, since most of it falls on the floor instead of penetrating into the room at bench or table level. The further the glass is raised above the floor, the further the light will penetrate. Unfortunately, the greater the height of the glazing the more likely it is that problems of glare will arise. The balance of gains and losses in the

final costs - in - use comparison will depend on the use of the building.

Cost of Capital:

A large proportion of industrial and commercial firms in fact rent rather than purchase their buildings because purchasing would increase their need for fixed capital to a serious extent. Many firms could not operate if they had to raise sufficient capital to finance the purchase of a building as well as to operate their business. Even if firms have the capital, they can often use it more profitably in their business than by investing it in their buildings. Often firms seek to increase their working capital by mortgaging their buildings, or by selling them to a property company and leasing them back.

Many other costs-in-use are considered in the book by
P.A.Stone "Building Design Evaluation Costs-in-Use" (Stone, 1967)

CHAPTER 6.CONTRACTSManagement Contracts:

This type of contract engages a management contractor to attend to all matters related to purchasing, negotiation, letting of subcontracts, insurance, engineering, and supervision of construction. The management contractor does not usually carry out any of the construction with his own forces except for its general supervision. This form of contract should be extended to include architectural and engineering design services. There are two main types of management contracts.

The contractor can be made the agent of the owner where all actions of the contractor are made in the name of the owner. Under the agency stipulation, the owner assumes full responsibility for all actions of the contractor and resulting money liabilities. However, by this arrangement, the owner engages the services of a concern possessed of a high degree of technical skill in construction and administration, whose sole interest is that of the owner.

The other type of management contract is that in which the usual independent contractor status is maintained, although the contractor is engaged in a managerial capacity only with the same duties as outlined previously. His own actions are now taken in his own name and on his own responsibility. The contractor pays all bills, generally from funds advanced by the owner for this

purpose. The contractor remains responsible for the work until its completion and acceptance by the owner.

Management contracts have a considerable advantage over design and build contracts because the architect-engineer is free to act as an agent to the owner. Also this larger broad-minded team has the interest of the client during construction and is better equipped at the preliminary design stage to advise on matters of value for money spent, overall control of construction costs, and future in-use costs. Finally, management contracts can gain maximum value for the client from other forms of contracts when letting of subcontracts. For example, the supply of clearly defined standard materials and services could be by open tendering lump sum contract, and for more difficult work where arrangement and new methods are important, a negotiated contract would enable the subcontractor to participate at the conceptual design stage.

Separate Contracts:

The economies of specialising subcontractors can be considerable and as a result the prime contractor has been forced to gain his profits from specialising himself or acting as a co-ordinator. The prime contractor often adds a fee to co-ordinate subcontractors, but this practice has legally been restricted in some states of America by requiring that separate mechanical and electrical contracts be awarded on public works.

There is no need for different homogeneous stages to be let as a single contract. An example is clearly demonstrated in bridge construction, where separate contracts are commonly awarded for such typical subdivisions of work as the foundations and piers, the approach structures, the bridge superstructure, and the painting. The overall planning, detailed design, control and inspection comes under a management contract.

Most projects can be divided into homogeneous stages and some of these stages may involve work of a highly unpredictable nature which would almost certainly be let as a cost-plus contract. Work such as piling foundations of an uncertain depth can be let as a unit-price contract, and finally work which is clearly defined let as a lump sum contract.

Even contracts let as homogeneous stages must be coordinated with considerable skill but separate contracts within a single homogeneous stage can cause disputes and place subcontractors in a vulnerable position. Also innocent parties may claim damages and frustration of contract. However, small highly specialised teams moving between building sites to place materials is becoming a common form of site labour. Giving a small team of men a clearly defined job at a fixed price develops skill, efficiency, job satisfaction and motivation that cannot be matched by a single large team doing many jobs under the control of a foreman. The advantages of many separate contracts on say a city office block

considerably outweighs the disadvantages provided sufficient thought is given to construction organisation at the conceptual stage of a project.

Many separate contracts will enable design teams to obtain and control the total price of a project. For example one of the most variable costs that is difficult to control is that for structural foundations. This is an early cost which can be absorbed within the cost limit. Following costs can be estimated reasonably accurately and finalised after detailed design is completed. A cost which often seems to fluctuate beyond reasonable control is that of finishes and services. These are late costs which can be accurately estimated by design teams and can be used to control costs, without seriously affecting the agreed overall value, before finally being put to subcontractors for tender price.

It is extremely important that a project subdivided for economic and control reasons must be carefully planned. The principles of control must apply to both timing and costs for all stages of a project.

Design and Build Contracts:

The case against design and build contracts is illustrated in the following example. The report of the Royal Commission on the King Street Bridge Contract in Melbourne shows how a design and build contract had failed to ensure professional responsibility

and authority. In the Melbourne case the contractor, when tendering, purchased plans from a group of engineers, and submitted them with his tender. The tender was accepted, but thereafter the design group was not engaged, and when the bridge failed by developing many cracks and fractures in the welded joints, it was clear that the employer and his engineering service, though concerned over some of the techniques, had insufficient effective engineering control. Likewise, the contractor was not technically able to avoid disaster. (Turner, 1966).

The need for inspection during construction, to ensure that the contract is properly executed and that the owner's interests are protected, creates the "toughest job in construction". Because this job is absent or carries ineffective power under design and build contracts the client is involving himself in very costly risks. Even if the client employs an independent inspector, disputes can easily arise over matters of ill-defined quality and only engineering designers know how critical the quality of materials are to satisfy design strength.

However, even the most experienced clients are tempted and prepared to take such risks when offered a building in the form of a "package deal" with a guaranteed price and completion time. This indicates that the disadvantages of design and build contracts are sometimes no worse than the inability of traditional independent design consultants to satisfy the client's needs.

CHAPTER 7.

PREFABRICATION CONCEPT

The building industry is basically an assembly industry and the trend towards off site manufacture and on site construction assembly is gaining momentum throughout the world. Prefabricated elements have long been known in the form of the small clay brick, roofing tile, concrete block, etc. Also internal fixtures such as bathroom and kitchen units are examples of larger prefabricated elements.

Large cranes and transportation made possible the prefabrication of individual room elements for a 21 storey Hilton Hotel in Texas, which was completed within 8 months from initial excavation to first occupancy. The room elements weighing 35 tons each were even completed to include furnishings in a casting yard 8 miles from the site. The construction cost figures indicated that these large prefabricated elements resulted in considerable savings compared with traditional construction. (Jacobs & Schneller, 1971).

The prefabrication concept applied to the building industry has already proven itself in reducing construction costs and improving efficiency. However, there are many factors contributing to the economies of prefabrication and the blind application of prefabricated units has sometimes resulted in far higher costs than traditional construction.

Probably the biggest single factor contributing to the success of prefabrication is that of logical and orderly organisation. The

total design must be solved before construction operations begin and the use of expensive cranes and transport must be carefully planned to gain overall efficiency. Also the organisation of labour must be appropriate. The prefabricated elements can be divided into homogeneous stages of on site construction assembly and the specialised labour teams must also be organised in a similar way. It is a serious mistake to organise labour teams according to trade, and it is completely unnecessary to employ the same work force for the duration of the project, with all the problems of trying to balance labour requirements. Each homogeneous stage performed by a specialised team should be let as a separate subcontract.

Other major factors contributing to the success of prefabrication include invention, simplicity, repetition, standardisation and specialisation. All these factors are interrelated; for example, simplicity of on site assembly is important, though processes that are normally considered complex on site can be cheaply carried out with off site manufacture, using repetition, standardisation and specialisation under factory conditions.

The overall economies of standardisation are so powerful that we cannot afford to neglect it. From a high degree of standardisation has evolved the "system building" or "industrialised building" techniques. However, there are misconceptions and resistance to change about system building on grounds such that all buildings look alike, and of too rigid standardisation. Provided that proper

modular dimensions are used such as 4 in, or 10 cm as is common on the European continent, building components made by several firms will be interchangeable. Also constant storey heights for certain types of buildings so that stairs, wall units and other internal fixtures can be manufactured to suit most future buildings. A large variety of different surfaces are also available; ceramic, polished concrete, tiles, exposed aggregate of all types, coloured and textured concrete, in addition to brick.

The use of skilled labour has been reduced by the use of prefabricated materials and components, for example, the use of prefabricated joinery for cupboard units, and the use of prefabricated tile work for fireplace surrounds. This process could be taken a great deal further. Moreover, the amount of skill needed in a craftsman is declining. Carpenters and joiners no longer fashion elaborate work on the site; modern adhesives and metal fasteners simplify jointing; bricklayers are only called upon for the most straightforward types of brickwork and plasterers only carry out straightforward plastering. In fact, large prefabricated panels completely eliminate the need for some trades, such as plastering. Generally it is only in the rare new building and in restoration work that the craftsman can exercise his full range of skills. For most work it is possible that craftsmen of adequate skill could be trained much more rapidly than at present.

CHAPTER 8.

SUBCONTRACTORS

Subcontractors generally carry out a high percentage of construction. This report considers all construction work let under many separate contracts to specialised subcontractors and these being co-ordinated by a single management contract.

Organising Site Labour:

The Banwell Committee report to the British Government in 1964 reminds us that nearly a third of the labour force which the construction industry employs is engaged on repair and maintenance work and that nearly 90 per cent of the firms in the construction industry employ less than 20 persons. (Banwell, 1964).

Small teams of construction labour have proven themselves as an efficient and competitive form of labour. The trend on new city building sites is for further specialisation with small teams employed on the site to do a clearly defined job at a fixed price. An example is illustrated by the supply and placing of reinforcing steel. The steel suppliers prefabricate the reinforcing bars which are delivered to the site and placed by a small team under contract. Also the construction of a suspended concrete floor can be divided into three homogeneous stages; the supply and placing of the precast floor units, the supply and placing of reinforcing steel, and finally the supply and placing of the in situ concrete floor screed. The supply and placing is often carried out by different firms working together

All these firms rely on a number of construction sites for constant employment.

This high degree of specialisation has brought about considerable economies because mechanical equipment is able to be constantly employed and the labour achieves considerable skill and efficiency. Also these small teams commonly enjoy profit sharing and self motivation.

The success of this degree of specialisation depends on the skill with which it is co-ordinated. Most building projects tend to be very complex and careful planning is the key to increased productivity. Careful consideration by the co-ordinator towards the specialized teams will return similar service from the specialists.

Cost Proportions:

The two major elements of building costs are labour and materials. Their proportions depend on the type of building and the relative local levels of prices. In Britain about a half of the value of building work is represented by the costs of materials, one third is the cost of labour, and about a sixth to overheads and profits. In America the cost of labour is slightly higher than the cost of materials. Generally the ratio of overheads and profits in the construction industry is fairly low. This is probably partly a result of a low use of management skills and low capitalisation (Stone, 1966).

One of the main themes of this report is to inquire into how the building industry can improve its productivity. Studies on the productivity differential between Western Europe and the United States (for instance, one made by the Stanford Research Institute) showed quite clearly that it is not a matter of capital investment. In many European industries capital investment and equipment were found to be fully equal to America; yet productivity was as much as two thirds below that of the corresponding American industry. The only explanation is the lower proportion of managers and technicians and the poor organisation structure of European industry with its reliance on manual skill. (Drucker, 1968). In other words, a higher proportion of costs directed towards management skill to plan and co-ordinate subcontractors should increase productivity in the building industry.

Management of Subcontractors:

Standards of honesty and competence along with the ability to comply with a programme are vital factors in securing value for the money paid to subcontractors. However, price alone is traditionally the only factor considered and hence the wide use of the open tendering system.

Subcontractors under the control of a general contractor are subjected to considerable abuse, and the fair practices between the client and the general contractor may not apply.

Foremost is the practice known as "bid shopping" in which after the general contract is awarded, the successful contractor endeavors to obtain bids lower than those originally submitted. On the other side of the picture is the practice of "bid peddling" where the successful general contractor is offered lower prices by unsuccessful subcontract bidders than those he used in preparing his winning bid. These practices if left unchecked, tend to drive out the more competent major subcontractors who prepare valid bids for quality work.

The open tendering system involves many subcontractors in considerable expense in preparing unsuccessful tenders. Also because a subcontractor may win all or none of submitted tenders he is often over or under committed. This means the subcontractor is unable to maintain an efficient level of work and if over committed he has difficulty complying with a programme. Every subcontractor must make a profit to survive and so such expenses must be paid by the client.

The Banwell Report recommends a measure of selection in regard to the suitability of the subcontractors before tenders are invited. The committee believes that there are occasions when even selective competitive tendering is not appropriate and direct negotiation with two or three subcontractors or even a single firm may be preferable. (Banwell, 1964). Sometimes a client or his agent will negotiate with a subcontractor and then require the general contractor when he tenders to adopt the subcontractor

subject to reasonable objection.

Serial Contracting:

The construction industry has been criticised for its casual methods of employing labour. This problem can only be overcome by long term programmes rather than considering construction as individual jobs in isolation.

Serial contracting involves a system whereby a contractor who is successful in an initial competition is assured, subject to his giving satisfactory service, of a prescribed programme of further suitable work on agreed terms, the rates and prices for the first job being used as the basis for the remainder of the programme. This system offers incentives to subcontractors to maintain a high standard of workmanship and co-operation, and produces savings in time by eliminating lengthy pre-contract procedures for each project in a programme.

Serial contracting could be arranged on legal terms or mutual confidence. There are many cases of long standing and highly satisfactory relationships between clients and contractors based on mutual confidence and that such relationships can lead to speedy, economical and skilful satisfaction of the client's requirements without resort to conventional competition. (Banwell, 1964).

CHAPTER 9.

SUMMARY AND CONCLUSION

Techniques to co-ordinate and measure the skill with which designers and planners commit resources is a very important step towards creating a working unity between developer, architect, engineer and management contractor. The procedures and organisation should permit the flow of information for the mutual benefit of the industry as a whole. The type of organisation examined in this report has the incentive to act in the best interests of the client and to achieve the economies of co-ordinated specialisation.

Cost control in building design keeps expenditure within the amount allowed by the client, gives the client good value for money, and achieves the required balance of expenditure between the various parts of the building. Like other control techniques, such as critical path, there must be a frame of reference, there must be a method of checking, and there must be a means of remedial action. The frame of reference consists of first establishing a realistic first estimate based on the function of the building, then planning how this estimate should be spent among the elements of the building.

The building industry is basically an assembly industry producing large unique products. Although each client's requirements differ, a considerable degree of standardisation is possible.

Further prefabrication of building components is inevitable, but considerable thought must be given to site organisation of machinery, materials and labour. The site labour should work as specialised teams under financial incentives and each within a clearly defined homogeneous stage to avoid interference. The establishment of competent teams which have the ability to comply with a programme should be assisted with constant employment between building sites.

From the examples given and the considerations discussed, it is concluded that improvement of productivity in the building industry would best be sought along the lines of organisation described.

REFERENCESANONYMOUS,

1968 a "Plan of Work : Research Laboratory at Newcastle-upon-Tyne" (Architects' Journal", London pp 1085 Nov. 6)

1968b "Cost Control in Building Design": R & D Building Management Handbook 4. (Ministry of Public Building and Works, London. HMSO)

ARUP, O.,

1968 "Balanced and Total Design"
("Surveyor", London Nov. 23)

BANWELL, G.H. (Chairman),

1964 "The Placing and Management of Contracts for Building and Civil Engineering Work" : Report of the Committee
(Ministry of Public Building and Works, London HMSO)

BISHOP, D. & ALSOP, K.,

1969 "A Study of Coding and Data Co-ordination for the Construction Industry" : Building Research Station.
(Ministry of Public Building and Works, London. HMSO)

CLOUGH, R.H.,

1960 "Construction Contracting"

(Wiley, New York)

CORRADI, P.

1971 "A Profile of the Future Construction System"

(A.S.C.E. Journal, Construction Division pp 149 March)

DRUCKER, P.F.,

1968 "The Practice of Management"

(Pan, London)

FELD, J.,

1968 "Construction Failure"

(Wiley, New York)

JACOB, J.D. & SCHNELLER, F.,

1971 "The Prefabrication Concept - Off Site Manufacture -

On Site Construction Assembly" (A.S.C.E. Journal,

Construction Division pp 155 March)

LU, F.F.S.,

1969 "Economic Decision-making for Engineers and
Managers"

(Whitcombe & Tombs, Christchurch)

ROYAL INSTITUTE OF BRITISH ARCHITECTS,

"Handbook of Architectural Practice and Management"

(The Institute, London)

ROYAL COMMISSION

1971 Report into the Failure of West Gate Bridge

(Govt. Printer, Melbourne)

STEELE, R.W.,

1971 "Engineering - Accounting Relationships in Management"

("New Zealand Engineering" Vol. 26, No. 8 : August 15)

STONE, P.A.,

1966 "Building Economy" (Pergamon Press, Oxford)

1967 "Building Design Evaluation, Costs-in-Use"

(Spon, London)

TURNER, C.W.O.,

1966 "Contracts and Contract Administration"

(Govt. Printer, Wellington N.Z.)