BUILDING SITE ACTIVITY

AN INPUT/OUTPUT MODEL

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CHAPTER I

INTRODUCTION

1.1 GENERAL

The Construction Industry accounts for about half the annual fixed investment of the country, hence their national productivity is a key factor in raising annual efficiency. During recent years the importance of achieving productivity in the Building Industry has been frequently referred to in the technical press and also at public meetings. Research into the construction industry is being conducted by several research organisations and in the universities. A research team sponsored by the Department of Scientific and Industrial Research (now Ministry of Technology) is working in close collaboration with several Professors at The Manchester College of Science and Technology to look into the Structure and Economy of the Building Industry (S.E.B.I.). Among other Government sponsored organisations conducting research into the building industry are B.R.S. and N.B.A.

The magnitude of the industry and its significance to the National Economy is illustrated by the fact that nearly $1\frac{3}{4}$ million operatives were employed by the building industry and the value of output exceeded £3614 million in 1964.

The output of the construction industry has increased by 61.4% since 1958(in the last 6 years). To keep up with this the construction industry is faced with an enormous and challenging task.

A study carried out by the National Economic Development Council estimated the demand figures for 1964 and 1966 (the Study report was published in 1964). They estimated that if the estimated output of 1966 has to be met, the output must increase by 24% over the level of 1963. The labour force must be increased by 8% over the level of 1963. The required increase in labour productivity will be about 15%. Most of the increases in labour should consist of craftsmen and should include a high proportion of skilled men.

If output through improvements in productivity is to increase more rapidly than in the past, changes which have been taking place over a number of years will have to be accelerated. These changes should be in the following four directions.

1) Improvements in the organisation of demand.
2) Improvements in management techniques.
3) Further mechanisation and introduction of new techniques.
4) Increase in research into operational methods and in the quicker dissemination of research results and information.

The complexity has increased in the construction industry, as more of the professions and specialists are involved. (S.E.B.I. Table).

The whole process of building from conception to completion can be broken down into the following phases:-

Phase 1 - Client deciding to build.

Phase 2 - Client consulting Architect or Building Team Sponsor.

Phase 3 - Architect investigating and preparing the brief.

Phase 4 - Preparing and getting Client's acceptance of Sketch plans.

Phase 5 - Preparation of the Bills of Quantities and making the Contract Document.

Phase 6 - Selection of Main Contractor.

Phase 7 - Selection of Sub-contractor and setting up a complete construction team.

Phase 8 - Construction to completion. The complete activity on the site.

Phase 9 - Handing over and settling Final Account.

Thus these nine phases in the building process consist of three main stages:-

1) Brief and Design Stage.

2) Construction Planning Stage.

3) Actual Construction Stage.

It is felt that there is scope for improvement in management techniques at every level of the building process, particularly in the actual construction stage. A building site with good organisation, good equipment and effective communication system may still be inefficient, because it does not make effective use of its resources, i.e. due to lack of operational control. This is obtained by efficient decision

making by those who manage the operations, particularly the full-time Site Manager.

Study of the effective utilisation of economic resources is a well-established domain of interest to the sub-group in economics which concerns itself with Micro-Economics and Econometrics. Concurrent with this development there has been another which deals with the broader class of resources and consequently with a wider variety of organisational decision problems. This broader inter-disciplinary approach to Operational Control is called Operations Research.

The essential characteristics of this interdisciplinary activity lies in its methodology. Out of the study and analysis of operations it seeks to develop a measure of Performance 'P' of the system. It then seeks to develop a Model of the system in the form

$$P = f\ (C_i\ ,\ U_i)$$

where C_i = Management controls

U_i = Aspects which are beyond management control

Unfortunately, in many cases, such a model of a system cannot be constructed because of lack of existing measure of performance, and lack of evaluating the "management control" factors. As a result such a model has to be based on observations, scientific analysis and intuition or subjective judgments.

By virtue of non-repetitive characteristics of work at the building site, the problems of managing i.e. planning, control and co-ordinating of the work at the building site involves more complex decision making mechanics. The management control factors are more difficult to evaluate.

Techniques have been developed for planning and control of building site operations and are already being used in some of the more advanced and larger units of the industry. In a study carried out by A.T. Pollock[1] at The Manchester College of Science and Technology to find out the Applicability of C.P.M. Techniques on the Building Site, he found that only on one building site out of thirteen, the network diagram was used all through the construction stage. In the remaining twelve sites, the network was given up during the construction stage, and they reverted back to conventional Bar-charts. This was due to the fact that at certain stages of the construction, the original Network became so far out of the actual progress on the site, that a new Network became essential. It is therefore necessary to study the management control functions before any of these sophisticated techniques are used on the site. This involves the study of problems at the site, their priorities, causes of delays, distribution of authorities at the site.

The logical plan would be to study the problems at the building site, where the work is actually being done. This above decision also dictates that in a study of this type, the site manager, who

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[1] A. T. Pollock - unpublished M.Sc. Thesis - Manchester College of Science and Technology.

plays an extremely important role on the building site should be included. His views and opinions ought to be ascertained and incorporated in a study of a model of the type mentioned above.

1.2 SURVEY OF PUBLISHED WORK

Considerable research has been done by professional and non-professional research organisations and individual research workers into the different facets of the industry. A detailed bibliography has been provided at the end. A very brief resume of the work which is relevant to this work is given below.

The functions of the Site Manager on the building site have only recently become the object of systematic study, and even so, to a limited extent. In the 1950's Dr. Mejse Jacobsson was the first to make some fundamental researches in this field with the help of conventional work study techniques.

In the middle of the 1950's in the United States of America, application began to be made of frequency study techniques with reference to observational work as such and which were particularly suited for the site manager's highly diversified activities.

The first attempt to classify the tasks which site manager carry out, was made by Building Research Council of Sweden. In their publication entitled "Functions of Supervisors in the Building Industry" by Hans Wirdemus and Sterner Lonnsjo they studied the work pattern of site managers. The report contains a description of work sampling

methods as applicable to the building sites. They also give an analysis of the working requirements for constructional supervisors and also provide a basis for recruiting and training of site managers. Similar research was carried out by Reynaud. In his unpublished thesis entitled "Building Site Managers" he discusses the roles and responsibilities of the site managers in relation to the time he has to spend on various activities.

In a study carried out by the Institute of Builders, they have discussed the need to improve the quality of site management. The report entitled "Construction Management in Building, Present and Future" was published in January 1965. The report seems to be more concerned with the contract management rather than with management on the site. This report appears to be biased because the responsibilities which have been laid out for the site managers are based on the opinions expressed by the central management of the firms. No attempt was made in this study to relate their findings with the actual conditions on the building site. No attempt was made to study from the site managers point of view, the relative importance of those aspects of his work which he sees as contributing most to an effective end result, neither have they tried to measure the distribution of control between the site management and central management.

Research is also being conducted in B.R.S. to Study the decision rules for more effective site control. The first attempt

to use the concepts of operations research in the Building Industry was made by Tavistock Institute of Human Relations. Their report entitled "Building Industry Communications Research Project, Realisation Report" was published in August 1965. In this report they have dealt with the general problems of communications in the Building Industry. They have made an attempt to determine the nature of non-technical factors which determine the present division of responsibility between the roles of all those responsible for the building process and how it affects the overall performance. They have discussed the effects of interdependance between the different members and the existing uncertainties in construction process on the design process in an attempt to devise decision rules for design methods.

In none of the above mentioned publications has any attempt been made to study an important organisational input into the industry which is the experience, judgement, wisdom and the skill of the men who are in fact in charge of the construction process on site.

The importance of this particular organisational input in improving the overall performance of the industry was mentioned by Lickert Rensis in his book "New Patterns of Management". Professor R. W. Revans devised statistical methods for measuring these inputs quantitatively in order to determine the causes of wastage in hospitals.

1.3 OBJECTIVE

In this study which was carried out on projects which were also investigated by D.S.I.R. Research Group, an attempt has been made

1) to develop the techniques of measuring the extent of site control of the building operations exercised by the full-time site manager.

2) to study one of the organisational inputs which is the experience, judgement, wisdom and skill of the man in charge on the building site in order to develop indices of performance.

3) to devise an index of operational control based on the fluctuation in the labour force employed on site.

and to incorporate the indices in a model of building site activity with a view to studying the problems arising on the building site and make suitable recommendations.

CHAPTER 2

This Chapter deals with the methods used in this Study. The Study was carried out in two distinct phases. They are discussed below.

2.1 Phase I

It was realised from the outset that any study which deals with the activities on the building site must be started with an intensive study of site. It was obvious that a research of this kind could not encompass the whole of the building process (9 phases discussed in the previous chapter) from conception to completion. With this view in mind two firms were approached to seek their permission for such a study. The two building sites were chosen because they offered the opportunity to do an intensive study of the construction operations going on on the site. Both the projects were fairly large (£1¼ million and £0.8 million) and it was expected they would give quite an extensive picture of the activities on a building site.

As it was essential to get the permission of all the parties concerned, i.e. the Architect, Client, Main Contractor and the Quantity Surveyor, letters were written to them seeking their co-operation. This was done through the S.E.B.I. Research Project.

In undertaking the field work it was understood that contacts with all the persons and organisations were to be treated in the strictest confidence. It was made plain to the parties concerned that no information would be passed on to anyone else, even to the members of the same building team.

The response was very good and both the firms agreed to such an investigation being carried on their sites. Both firms accorded the author full access to all written records (including daily correspondence). Permission was also given to sit in at any meetings and to be present during discussions between parties.

The intensive study was carried out in an attempt to get firsthand information of day to day problems, set backs, improvisations, and solutions in the construction phase "as it was happening".

Throughout the study a diary of events was kept, which recorded physical progress of the job, conversations with the personnel, and with the visiting consultants and sub-contractors, details of correspondence and telephone calls to and from the site and the minutes of the site meetings. Interviews and discussions were held freely during the stay at the sites. Most members of the building teams were found to be eager to help whenever their collaboration was sought. Frequent visits were made to the Head Office, whenever it was found necessary to extract certain information. Among typical events that were observed were the daily state of work in progress, the arrival and departure of plant and equipment, the

movement of labour and materials, methods and decisions taken to overcome difficulties as they occurred in the course of the day's work.

As it was not possible to be present personally through the briefing stage, information was collected wherever possible by looking through site records, correspondence, and by interviewing and discussing the points with persons who were involved in the briefing stage.

Four and two months were spent on the first and second sites respectively. Both were visited when work had already commenced.

Site No. 1 was visited when work had already been in progress for one year. The second site was visited when work had just commenced and the Main Contractors had spent about three months on the site. In both the detailed studies considerable time was spent with the Site Manager, to find out the process of decision making and the distribution of authorities.

These studies have been described in considerable detail in Chapter 3. Extracts from the diaries and correspondence have been given where it was considered relevant.

2.2 Phase II

When the first phase of the study was completed, the author decided to change from the M.Sc. course to the Ph.D. course. It was realised that the information which had been collected at this

stage needed amplification over a larger sample, which would be more representative of the building site activities as a whole.

Sample Selection

This was achieved with the help of the D.S.I.R. Research Project. Two factors were taken into account for the selection of Projects.

(1) Limiting the choice of projects to those due for completion in the latter months of 1964 or early months of 1965.

(2) Rejecting contracts of under £25,000 value.

It was decided to approach firms, asking them if they would co-operate in the study, and requesting a list of projects conforming to sample control. Organisations were to be graded by size and thus the approach was made through the regional offices of the Federation of Building Trades Employers. Assistance from firms within the London Master Builders' Association came by direct approach and through the good offices of the members of the D.S.I.R. Research Project. From the Southern Federation of Building Trades Employers the Research Director of D.S.I.R. Research Project arranged to speak to meetings of Local Associations and so solicit support.

It was clear that in the Public Authority building sector, particularly where samples of Consortium-built schools and housing were concerned, requests for similar lists from recommended authorities would probably lead more directly to suitable contracts. A parallel request was thus made with the advice from appropriate Ministries.

Altogether 118 replies were recorded, from which selections were made. It was realised that in order to carry out the study, the participation of all the parties concerned was essential. With this view in mind the principal parties were approached, to seek their permission and establish the final sample.

This above sample, was also used for the Study C (Project Study) of the D.S.I.R. Research Project and 538 projects were listed. Table No. 1 gives distribution of projects by size. The Table also gives project reference numbers. Fig. 1 give a histogram of distribution of projects by size.

After the selection of the projects which were to be included in the Study, it was decided to visit these sites.

The Sites were divided into two groups. The first group consisted of 26 sites, out of the total number of 118 in the sample. The division was completely at random. This first group was chosen for the ranking study discussed in Chapter 5. Letters were written to the Architects and firms concerned seeking their permission for such a visit. The list of the 26 projects is given in Table No. 2 It was made clear to them that these visits would last about two hours or in exceptional cases a little longer. It was also realised that the success of such visits would depend largely upon the voluntary co-operation of all grades of staff, mainly the Site Manager and Project Manager, and upon a guarantee that the information offered was both confidential and anonymous, if so desired. Adequate attention was given to these points in the present study. A letter

Size of Project	Project Ref. No.	Total No.
£50,000	P/301, P/281, P/67, P/372, P/498, P/510, P/518, P/443, P/531,	9
£50,000 to £150,000	P/80, P/356, P/8, P/229, P/188, P/46, P/230, P/361, P/54, P/290, P/456, P/493, P/435, P/520, P/98, P/152, P/517, P/393, P/516, P/353, P/519, P/184, P/197, P/343, P/62, P/333, P/373, P/530, P/467 P/481, P/527, P/87, P/268, P/82, P/17, P/16, P/101, P/2, P/232, P/487. P/288, P/521, P/364,	43
£150,000 to £500,000	P/323, P/359, P/24, P/38, P/491, P/183, P/369, P/212, P/14, P/44, P/170, P/205, P/36, P/42, P/7, P/526, P/166, P/484, P/209, P/529, P/392, P/81, P/329, P/328, P/384, P/122, P/207, P/221, P/19, P/3, P/6, P/1,	32
£500,000 to £1,500,000	P/56, P/355c, P/334, P/11, P/28 P/29, P/198, P/339, P/119.	9
£1,500,000	P/294	1
	TOTAL	96

TABLE I

TABLE 2 Showing the Reference Numbers of Projects participating in the different parts of the Study

	Reference Numbers of the Projects	Total No. of Projects
Projects which took part in the Ranking Analysis	P/301, P/281, P/205, P/405, P/16, P/17, P/44, P/372, P/3, P/166, P/294, P/56, P/356, P/369, P/8, P/435, P/355c, P/230, P/6, P/36, P/80, P/229, P/323,	26
Projects taking part in analysis of response of Site Managers	P/56, P/11, P/14, P/24, P/28, P/29, P/54, P/6, P/87, P/188, P/198, P/207, P/232, P/290, P/339, P/359, P/467, P/491, P/520, P/527, P/529, P/528, P/36, P/435, P/323, P/456, P/294, P/516,	28
Projects which took part in the Study of Labour return	P/11, P/28, P/29, P/36, P/87, P/323, P/339, P/359, P/491, P/516, P/517, P/520, P/527, P/528	14

TABLE 2

was written by the Director of the D.S.I.R. Research Project to each of these firms explaining the purpose of the study and to the Site Managers. The recipients were invited to talk in confidence about any matters which were concerned with the work situation. The persons to be interviewed were Site Managers, Project Managers and if possible some of the tradesforemen.

The purpose of the visits were as follows:-

(1) To get a picture of the Site organisation; the general outlook of the responsibilities and authority of the Site Managers.

(2) The age, qualifications and experience of the full-time site supervisors.

(3) The position of the full-time site supervisors in the hierarchy of the firm, i.e. how far he is removed from the Directors.

(4) A general picture of the type of activities being carried out on the sites and the major causes of delays.

The Site Managers of these 26 sites were invited to take part in the "card game" described in Chapter 5 to estimate the ratings of the delegated site authority.

The interviews carried out on the sites were usually non-directive. They were encouraged to give their opinions on a variety of matters dealing with building management. Each Site Manager was interviewed separately so that there was no danger of

his being influenced by his Head Office representative or by the Architect's representative. The interviews usually started from the card game. While they were sifting and sorting the cards they were encouraged to discuss their particular arrangements of cards. This inevitably resulted in spontaneous comments on the problems of site control and site management. These interviews were used for the compilation of a questionnaire which was used for an attitude analysis discussed in Chapter 7. Questionnaires were also designed for the developing of rating index of delegated site authority and index of exercised site authority. This is described in Chapter 6.

The remainder of the sites were invited to take part in the Attitude Analysis (Chapter 8) and questionnaires were sent to them for determining the different indices mentioned above. To make sure that these questionnaires were clear to the Site Managers, it was decided to visit the sites. The rest of the site visits were made in conjunction with the D.S.I.R. Research Group. These visits were also used for getting the questionnaires of Study C of the D.S.I.R. project completed. The site visits were essential to find out if there were any particular points which otherwise would have been missed. The site visits obviously helped in increasing the participation ratio. Out of 40 questionnaires sent for attitude analysis only 28 were completed and returned. Work was already completed on some of the sites and it became very difficult to locate the Site Managers to get the questionnaire filled in. The list of sites which

completed the questionnaire for determining the indices of delegated and exercised site authority is given in Table 2.

During these visits a brief study of the type of programme used and how the programme was being following was discussed.

Figs. are given which show the distribution of Site Managers by age, experience and academic qualifications.

Twenty-eight projects were asked to give the weekly labour return figures which were used to develop an index of operational control of the building site and to find if there was any general pattern in labour utilisation. Only 14 sites could supply the information.

The Table No. 2 gives the reference numbers of the different projects which took part in the different studies.

In general the methods used were intensive site investigation studies, brief site visits, interviews and questionnaires. These were done in a logical sequence to utilise the information in a model of Building Site Activity.

CHAPTER 3

CASE STUDIES

3.1 Case Study A

General:-

This is a large firm of Building and Civil Engineering Contractors. The yearly turnover in recent years is of the order of £8 million. The number of hourly paid operatives is more than 1,000.

Company Policy:-

The minimum value of contracts undertaken is of the order of £10,000. This size of project is usually taken for the sake of continuity of work. In many cases these contracts are taken as a matter of policy, where they expect to get some bigger contract in future. The smaller contracts also give them an opportunity to train their site staff. There is no upper limit of contracts, sometimes only limited by the available resources.

The work done by the firm falls mainly under the following categories:-

(1) INDUSTRIAL BUILDING - Factory buildings constitutes the major part,

(2) OFFICE BUILDINGS - Mainly related to factory buildings, also includes laboratories etc.

(3) "PRESTIGE" BUILDINGS - which include university and other educational buildings.

Organisation of firm:-

The firm has five Directors. They are all executive directors and are in charge of the respective departments. The Chairman of the Board of Directors is not a working director. The organisation chart Fig. 2 gives the duties and responsibilities of the working directors.

The Project Managers were responsible for day to day running of site and co-ordinated the different service departments, which include Buying, Plant, Personnel, Planning and Design and Stores. This is one of the few building and civil engineering firms who had a Personnel Department. The Personnel department is headed by a Personnel Officer who is a member of Personnel Organisation.

The site was first visited in the second week of August, when the work was already in progress for about one year.

Preliminary discussions between the Client and the Architect took place in early 1960. The proposed site was visited jointly by the Architect and Client's representatives. The Architect had begun to form ideas on the position and layout of the building. The

ORGANISATION CHART OF FIRM

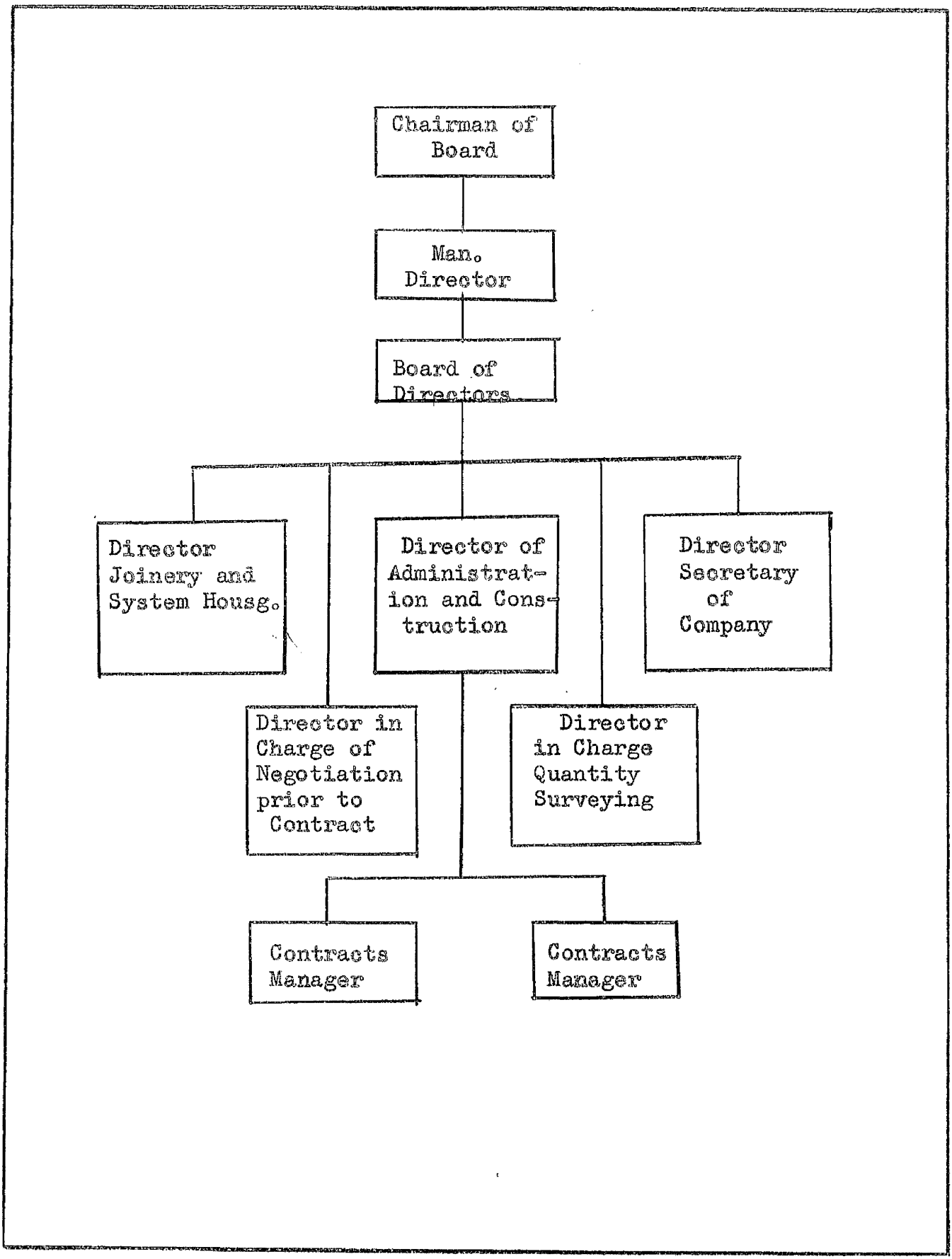


Fig. 2.

important considerations that the designer had to take into account were:-

(1) The new building had to fit into the extension scheme of the whole university campus.

(2) The building had to be designed so that it provided for the extension of the building.

(3) The Architect had to take into account the design of the existing buildings.

The preliminary brief prepared by the Architect was accepted by the Client in early 1961. The Bill of Quantities was prepared by the Quantity Surveyor within two months.

Description of Site:-

The site on which the investigation was carried out was part of a major educational development programme. The building consisted of three different functional blocks. The details of the buildings are as follows:-

a)	Superficial Area	Over 150,000 sq. ft.
b)	Cubic Feet	Over 2,500,000 cu. ft.
c)	No. of Stories	9

The scheme consisted of three blocks.

a)	Block A	Nine stories
b)	Block B	Seven stories
c)	Block C	Single storey

Site Administration:-

There were six staff members who represented the Main Contractor including the Site Agent. The work on the site was distributed between them, and all were answerable to the Site Agent. In addition to these were the representatives of the Sub-contractors and the Specialist Consultants. The Architects decided to appoint a Clerk of Works as their representative at the site. The organisation chart of the Main Contractor at the Site is given in Fig. 3.

A brief description of the nature of the work and responsibilities and authorities of the permanent staff is given below.

Site Agent

The Site Agent holds a University Degree in Civil Engineering. He started his career with the firm as Junior Site Foreman, and was gradually promoted to the position of Senior Site Agent. He is directly responsible to the Director-in-Charge of Contracts. He had worked with the firm as a Senior Site Agent for about ten years.

The Site Agent acts as the main co-ordinator between the site and other external systems in the building process. Although he believes in informality of an organisation, he insists that all communications from outside the site must be formally recorded. The Site had a complete record of correspondence which came in very useful in the investigation. Once the contract was awarded to the Main Contractor he worked in close co-operation with the planning department at the Head Office to prepare the contract programme. He was also present

SITE ADMINISTRATION CHART

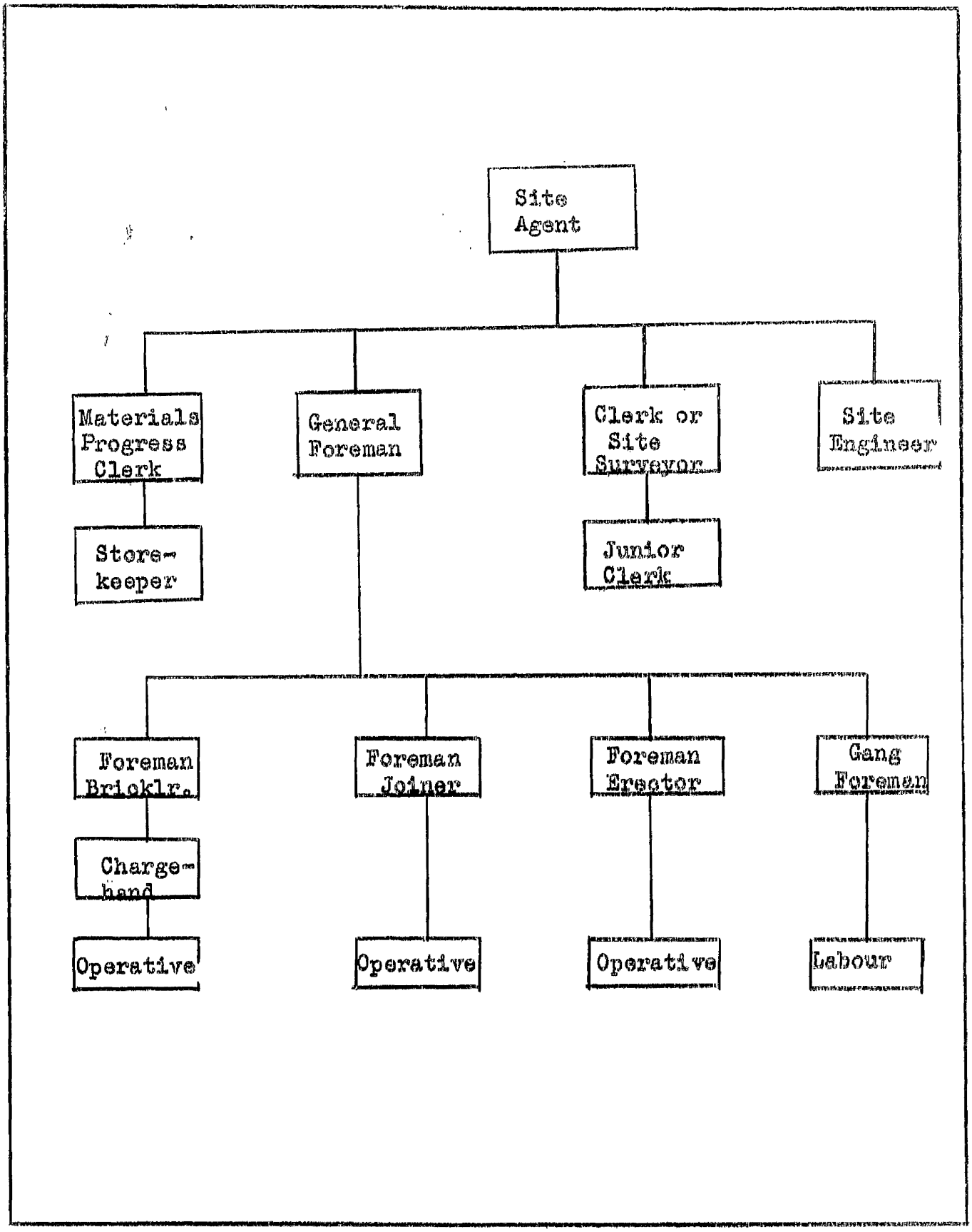


Fig. 3.

in the preliminary site meetings between the Architect, Client and Main Contractor before work started on site. He has strong views regarding participation in the preparation of the initial contract programme.

General Foreman

He was in charge of the construction work on the site, helped by different trades foremen. He acted as a co-ordinator between the different trades foremen. His responsibilities included general labour distribution and checking whether the work was progressing according to schedule and to report back to the Site Agent on day to day progress, especially those cases where delays had occurred. He worked in close co-operation with the Site Engineer to find out the specifications and variations and inform the foremen concerned in advance so that any alterations could be replanned. His responsibilities included unloading and placing of materials arriving on site, including sub-contractors materials. Quality control was also part of his duties.

Materials Progress Clerk

He was appointed on the site because of the size of the contract. Generally in a smaller contract (below about £50,000) his work would be done by the Site Agent or General Foreman, as the case may be. His job was to order the materials required for the Site through the chief buyer at the Head Office. He studied the main contract programme and with the help of the Site Agent and Planning Department prepared

a Materials Requirement Programme for major items of materials like bricks, precast concrete etc. In the case of shortage of materials or non-availability at the required time he chased them to make sure that they were delivered at the earliest possible time. In most cases he talked on the telephone to the supplier, but all the formal notes were sent through the Site Agent. It was the Site Agent who was ultimately responsible for the decisions.

In cases of alterations of the drawings or wrong specifications in the drawings, the foreman concerned reported the matter through the General Foreman to the Materials Progress Clerk. A formal letter was sent by the Materials Progress Clerk to the Architect through the Site Agent.

The Site store was also under the Materials Progress Clerk's control. The Storekeeper kept a regular record of all the materials delivered to the site and the amount consumed. The inventory of the materials was very approximate and in most cases figures were put in after a visual approximation.

Site Surveyor and Clerk

He was responsible for keeping daily records of labour including the overtime. Every Friday he measured the work done by different trade gangs to calculate the bonus. He was responsible for the valuation of the work done. In cases of disputes regarding bonus he worked in close conjunction with the Site Agent to settle all disputes.

Site Engineer

He was mainly responsible for the erection work at the site. All the drawings and specifications provided by the Architect were first sent to the Site Engineer to be checked by him. In cases of wrong specifications or alterations desirable he contacted the Architect through the Site Agent. The tower cranes were the responsibility of the Site Engineer.

Sequence of Events

The first formal meeting between the Architects, Main Contractor, and the Client's representatives was held in mid-1961. The Contractors were represented at the meeting by the Contracts Director, Contracts Manager and Site Agent. It was decided at the first meeting that the co-ordination on site would be maintained by formal and informal meetings. All the major decisions would be taken at the formal meetings which would be held in the first week of every month. The meetings would be chaired by the Architect. It was decided that the following should attend the meeting.

1) Architect
2) Representative of the Client
3) The Clerk of Works
4) The Representative from Head Office of the Main Contractor
5) Site Agent
6) Representatives of all the Sub-Contractors and Specialist Consultants.

The meeting would be convened and minuted by the Architect. At this meeting the Architect decided that a Clerk of Works (C.O.W.)

would be appointed. The C.O.W. could be queried for direction but could not instruct. His instructions would only be valid if confirmed in writing by the Architect.

The meeting would usually be classified under the following headings,

1) Progress of
   a) Structure
   b) Internal brickwork
   c) External brickwork
   d) Services, e.g. heating and ventilation, boilers, electrical fittings etc.
   e) Plastering, Finish
2) General Summary
3) Programming and revaluation of the Contracts Programme
4) Labour position
5) Materials position
6) Information regarding the availability of the different drawings
7) General points
8) Site tidiness
9) The date of the next meeting would be decided.

At this meeting decisions were taken regarding the appointment of Consulting Engineers. General points regarding the construction

programme, availability of drawings were discussed. The 1st March 1962 was decided as the tentative day for the Contractors to start work on site. This depended on getting clearance from the Town Planning Authorities. The Contractors made it clear that they would be finishing a few existing contracts by the middle of February, and would like assurance from the Architect about the exact date for commencing work on site. The Main Contractors were asked to submit to the Architect their draft working programme. The Architect gave the names of the Sub-contractors who were to be nominated.

The second preliminary formal meeting was held at the Architect's office on 26th February 1962. The meeting was attended by the representatives of the Architects, Main Contractor, Client and Consulting Engineers.

The Architect informed the Main Contractor that owing to circumstances which had arisen with the Town Planning Authorities, it would not be possible to start the work on 1st March as planned. It was hoped that a start would be possible on 1st April, all being well. In the meantime, the Main Contractors were told that nothing should be done on the site until further notice.

The Contractors tabled their draft working programme and it was agreed in principle by the Architects. The Main Contractors put forward the idea of using Pre-cast Techniques in the construction of the reinforced concrete frames instead of in-situ concrete operation. The Agent complained that if they used in-situ concreting methods, there

would be about 500 labour on the site at one time. They would have to depend to a vary large extent on the availability of labour. In the winter this could be a great hazard because the whole work could come to a stand still in the case of a bad winter. In-situ construction would also mean complications in handling of large amounts of aggregate and pouring of the concrete. This would mean introducing more uncertain factors which could cause delays.

The Architect and the Client both agreed to the suggestion in principle and asked the Contractor to provide them with greater detail at the next meeting.

The Contractors were asked to prepare the preliminary drawings showing the site accommodation and the general layout of the site offices, major plants. etc.

In the third week of March 1962, the Contractor formally complained to the Architect that they were eager to start work on site as soon as possible. An abstract from the letter is given to show the feelings of the Contractor....."We are now in a position where we have an abundance of labour which we cannot afford to maintain. We had hoped that there would be a logical transfer of labour from one of our sites which is closing, to this new contract, and in fact we have been carrying these men for sometime. In the absence of a fixed starting date, we have to dispose of them, as we are doubtful about recovering them.....Hopeful if you could see it fit to allow us on the site with boarding and temporary offices.....".

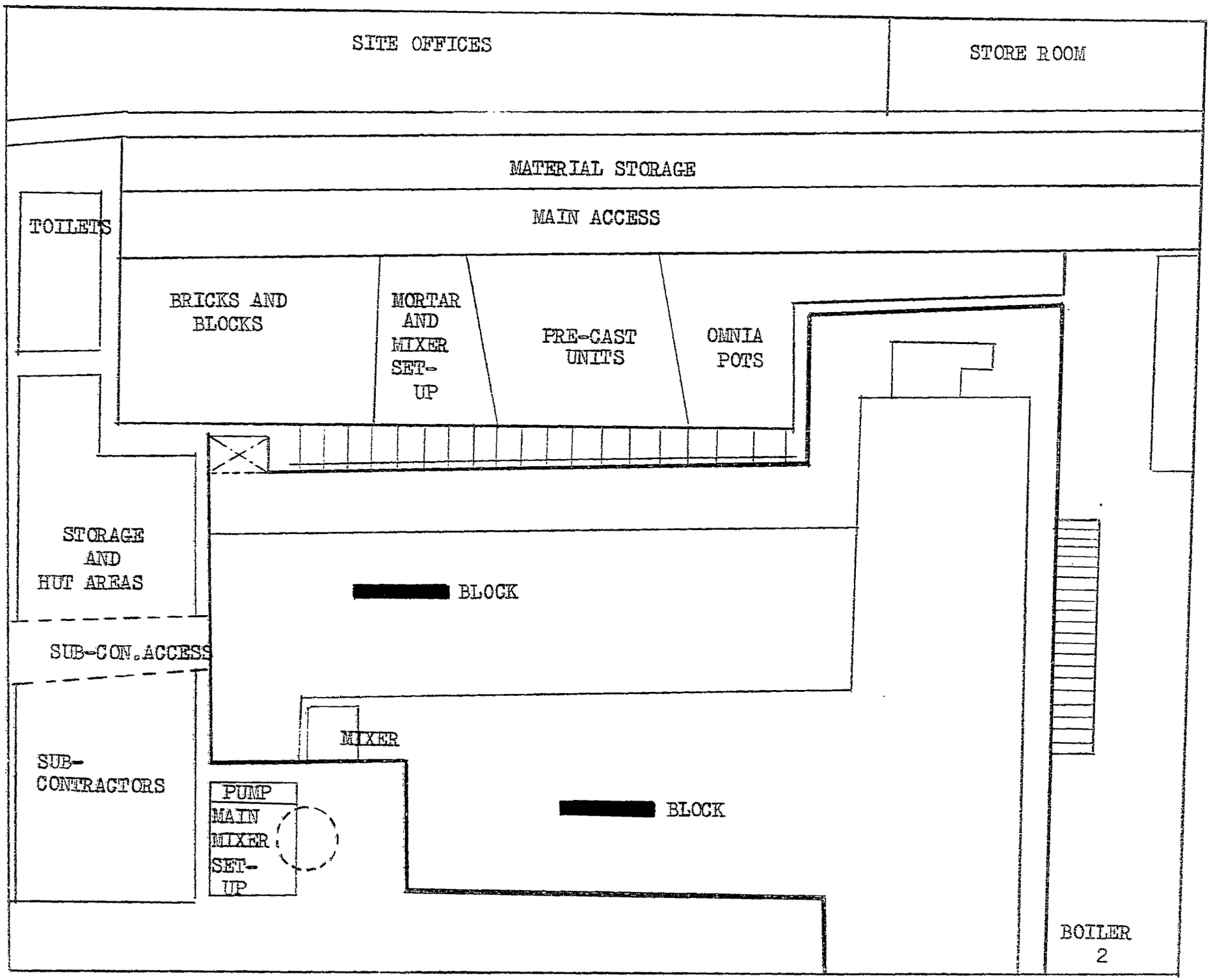
The Main Contractor submitted preliminary drawings showing the site accommodation and general layout of the site drawn by the Site Agent with the help of the Planner. The drawing was submitted to the Architects on 27 March 1962 for their approval. Under the contract document the layout has to be confirmed by the Architects.

The Architect asked the Contractor to make minor changes in the layout drawings and changed the main access to site from the main street, to one of the side streets to avoid the traffic problem. The revised layout was approved by the Architect on 13th April 1962. A copy of the layout drawings is shown in Fig. 4.

The Main Contractors were perturbed by rumours about the decision by the Town Planning Authorities regarding the building site, and the reasons for the delay. They complained to the Architects for not being able to start work at the site on 2nd April as previously decided.

In the third week of April the Architect reviewed the drawings for the basement plan. This enabled the Main Contractor to order the bulk of cast iron drains in the basement. The Consultants for Civil Engineering works were appointed by the Architect in consultation with the Main Contractor.

In May at the formal meeting the Architects discussed with the Main Contractor the question of information to be provided and they told the Main Contractor to put the latest dates for arrival of the drawings and incorporate this in the programme and send copies to the Architect and Specialist Consultants.


SITE OFFICES
STORE ROOM
MATERIAL STORAGE
MAIN ACCESS
TOILETS
BRICKS AND BLOCKS
MORTAR AND MIXER SET-UP
PRE-CAST UNITS
OMNIA POTS
STORAGE AND HUT AREAS
BLOCK
SUB-CON. ACCESS
MIXER
SUB-CONTRACTORS
PUMP
MAIN MIXER SET-UP
BLOCK
BOILER 2

In the middle of May the Contractors had received the provisional drawings for the sub-structure and some of the super-structure plans.

The first meeting on site was held in early June. Formal approval was given by the Architects to use pre-cast concrete beams instead of in-situ construction. The Contractors suggested that it would be better and advisable to use pre-cast structural members in the staircase areas of Research Blocks. This was accepted by the Architects in a formal letter. They were prepared to substitute pre-cast structural units, common brickwork and plaster decorated with emulsion paints as specified for facing brickwork and superfine finished structure. The Contractors were asked by the Architect to supply revised construction programmes incorporating the various items of nominated Sub-contractors.

The Sub-contractors for painting, polishing and mastic asphalte were approved by the Architect in the second week of July. The formal letter of approval by the Architects to the Main Contractor was sent in the third week of August.

The Contractor sent the revised copies of the construction programme to the Architect. This incorporated the various items for nominated sub-contractors.

An alternative scheme was suggested for substituting foam slag 1:3½:8½: thick in place of hollow clay pots as described in the Bill of Quantities, which was originally accepted by the Architect.

The Plastering Contractor's name was suggested by the Main Contractor to the Architect on 15th October 1962 and approved on the 22nd October. There was quite a controversy regarding the appointment of the Plastering Contractor. The Architects wished to nominate a firm with whom they had had previous dealings with and had found quite satisfactory. The Main Contractors absoluately refused to have them nominated and after much discussion the Architects agreed to the Contractor's decision.

At the December site meeting the Contractors suggested a change in the method of installing windows. This was an incident where prior consultation between the designer and the Contractors could have saved a lot of unnecesary delays. The Contractors had a subsidiary firm making windows and the Architects informed them to send written memo. explaining in detail the changes suggested.

In a letter to the Architects, the Contractor suggested that to avoid reorganising the whole system of window installation the following course of action could be taken:-

"(a) Windows manufactured and prepared for polishing and painting in one of their subsidiary companies.

(b) Delivered on the site in Pantechnicon.

(c) Stored on site in a specially prepared room at ground floor level in the Research Block. This room to be completed and kept weather-proofed, and at a suitable temperature and moisture constant.

(d) Primer coat and one undercoat to be applied in this room, to the painted surfaces and one coat of clear catalyst lagging to the polished surface.

(e) Windows fitted in position.

(f) Glazing fixed.

(g) Final coat of lacquer and final coats of paint applied at final decorating."

This was accepted by the Architects and a formal approval letter was sent in early December.

Although the dimensions of the windows were mentioned in the drawing supplied by the Architect and in the Bill of Quantities, dimensions (top and bottom) were taken at the site and sent to the Joiners' shop. The manufacture of the windows only started when the site dimensions arrived. All windows delivered to the site were stamped with the respective floor and window numbers. The Agent felt very strongly about this as it increased their work load on the site. On many occasions he complained that although the right dimensions with proper specifications were sent, the windows arrived in the wrong order and had to be stored on the site for a long time. This was due to bad liaison and inadequate authority in his possession. He could send the dimensions straight to the window manufacturers, but he was required to send all the dimensions through the Architects who were short staffed and consequently it took a long time to get the information moving.

He made a formal complaint to the Architects and to his Head Office and it was decided that in future all the dimensions would be sent straight to the manufacturers, with a copy to the Architects and Head Office. This should also contain the delivery note.

Complaints were made by the Main Contractors and the Sub-Contractors to the Architect, at the December meeting, regarding non-availability of information. Either the drawings were not available at the proper time or the information given was not clear. Both the Main Contractor and the Sub-contractors said that their work was suffering and they were already four weeks behind the schedule. This is an extract from a letter sent to the Architect by the Main Contractor....."We are quite prepared to do our share of sifting and sorting information, but it would be far easier and certainly more beneficial to us all if this information was clearly recorded either on the drawings, or on written instructions. We would like your consideration in this matter and whatever help you can give....".

In December 1962 the Architect gave his approval to using Pre-cast concrete beams instead of in-situ construction for reinforced concrete structural frames. Tenders for pre-casts were opened on 4th January 1963. A schedule was prepared by the Materials Progress Clerk with the help of the Site Engineer and Site Agent. It contained the specifications for the pre-cast concrete beams and the dates on which they would be required. The Contractors also decided that it

was essential to hire two tower cranes; one for erecting the pre-casts on the Teaching Block and the other for the pre-casts on the Research Block. The Site Agent realised that these pre-casts were very heavy (some of them weighing 3 tons) and big in size, therefore storage on site would be a great problem. Storing them also meant double handling. A very accurate preparation of schedule and a close liaison between the site and the suppliers was essential to avoid this problem. The pre-casts on arrival at the site could be easily lifted by the tower crane straight to the place of erection, from the lorry. After careful consideration and discussion between the Architects, Main Contractor and the Consulting Engineers, a firm near London was appointed as suppliers. This firm is an associate company of the Main Contractor. In this decision making mechanism the Site Agent played a very important part.

Another complaint was made to the Architect by the Main Contractor regarding the unavailability of the working drawings leading to the complete stoppage of internal brickwork in the Research Block. For sometime the bricklayers had no work. The Agent decided to switch work to get over this problem. While the bricklayers were kept idle, they were not only being paid their basic wages, but also the bonus. This was essential to keep them on the site, as there was an acute shortage of labour. The Site Agent switched the work from internal brickwork to facing bricks.

In the third week of January 1963, formal intimation was sent to the Architects, informing them about stoppages and delays in work

due to inclement weather conditions and lack of information. No formal request was made to the Architects to extend the completion date. The Site Agent decided to bring this up at the February site meeting.

The Contractors were having trouble keeping the labour on the site especially bricklayers and plasterers. This meant payment of extra bonus just to keep them on site. Though the payment of bonus to the workers was based on actual measurement of work done in a week, and not on the basis of spot bonus, the Contractors had to keep a minimum level of bonus. This was increased in the middle of February from 20% of basic wages to 28%. The Architects were informed of this decision by the Site Agent. In the opinion of the site staff the incentive scheme was fairly good and effective. The workers did not agree. They complained that the incentive schemes were all meant for management and the workers did not gain at all. They seemed to get the same bonus every week, irrespective of output. This was found to be the major cause of discontent among the workers and no measures were taken to explain to them the incentive scheme. This resulted in lower output as the workers refused to work beyond a certain minimum pace.

There was a delay in supply of bricks, both facing and common bricks. Although a programme was made by the Materials Progress Clerk for brick requirements giving the dates and sent to the suppliers in advance. There was a national shortage of bricks at the time and the

Site Agent decided to order well in advance and store the extra bricks on the site. The Site Agent got over this problem by switching works and redistribution of work. The decision had to be made instantly and this meant a change in the contracts programme.

The Site meetings were of two kinds. The formal meeting which was held every month and was described earlier and the informal site meeting which was held every week. This meeting was chaired by the Site Agent. No minutes were kept and all representatives of sub-contractors, the General Foreman, Trades Foremen, Site Engineer and the Materials Progress Clerk attended. The meeting was primarily held to sort out the problems which occurred on site. If any delay took place due to the fault of any member the reasons were discussed and if possible a solution was arrived at. They also discussed the progress of the job and it helped the Site Agent to send his weekly report to Head Office.

A formal letter was sent to the Architects in the second week of February by the Main Contractor requesting an extension of the completion date. The following reasons were given:-

(a) Non-availability of information

(b) Inclement weather conditions

(c) Labour shortage

This request by the Contractor was discussed at the March Site meeting. The Architects agreed to an extension of 2 weeks and 3 days, due to inclement weather conditions. Regarding the request for an extension due to non-availability of information, the Contractors were requested to redraw the programme, with arrows showing the latest

dates for arrival of information. Copies of this were to be forwarded not only to the Architects and Engineers, but also to the C.O.W., Heating and Electrical Engineers and all the Sub-contractors. The Architects advised that all the drawings should be sent through the Main Contractor. The Contractors were requested to keep a record of all the drawings issued. Though this meant more work for the Main Contractors the Site Agent agreed that this resulted in a smoother flow of information. The Site Agent also knew exactly what information was available.

Work was held up again in May due to non-availability of duct-cover drawings. The Site Agent wrote to the Engineering works concerned explaining to them that the work on the sixth floor could not be started. This was another incident of misdirection of drawings. The drawings and the specification details were sent to the Architects. They were finally traced to the Architects' office where they had been delayed for more than a month. The delay resulted in an exchange of letters and telephone calls and a great deal of time could have been saved if the drawings had been sent direct to the Contractor with a copy to the Architect.

The Contractors were having trouble getting aggregates for concrete mixing. The Site Agent decided to switch to ready mixed concrete against the alternative of high priced aggregates. There was no time to consult Head Office so the Site Agent made the decision informing the Architect later. The Head Office objected to the Site

Agent making such a decision but his reply was that the organisation and control in the Building Industry should be more flexible and be centralised on the site. Delays due to late decisions were extremely high and he believed in formal delegation of responsibilities and authority, but with more flexibility in the organisation.

There was an acute labour shortage during July 1963. There were also minor labour troubles, the main complaint being insufficient bonuses. The Site Agent found it extremely difficult to recruit labour on site as the shortage of bricklayers and plasterers was nationwide. The work was put about 2 weeks behind schedule and the Architects refused to extend time on the basis of industrial disputes. They felt that an extension of time in respect of industrial disputes was only allowable when these were general to the locality. Disputes which were related to one particular site were a matter of faulty management techniques.

At a working site meeting held the same day, the Contractors announced that due to certain factors not envisaged when the original plan was developed, and to subsequent delays, a new programme was to be made. Certain operations had to be condensed if the target date was to be attained. The Site Agent suggested that the critical events were 'pre-cast erection programme' and 'heating date'. A new programme was drawn out by the Site Agent with the help of the Site Engineer and a copy was handed to the Architects for approval, with a request that copies be issued to all concerned.

The first visit to the site was made in the first week of August 1963, several days were first spent getting familiar with the work in progress. This was done by compiling a brief note of the state of all the work on site and various building operations in progress.

The first impression recorded during discussions with the Site Agent and foremen was their dissatisfaction with the available drawings and instructions. In several instances, they have been provided with $\frac{1}{8}$" scale drawings ($\frac{1}{8}$" = 1 foot). They said that this scale was too small and caused them to work slowly to avoid mistakes.

August 1963:-

The new programme was duly approved by the Architects. At this time work was already four weeks behind schedule.

The Consulting Electrical Engineer asked for details of the Client's electrical requirements, so that the Electricity Board had ample time to obtain a suitable transformer. He also reported that the main intake panel would be brought into the building via the staircase. A doorway was to be widened to give easier access.

One of the Foremen noticed that the sand arriving at the site contained small stones. The mortar made from this sand was not suitable for bricklaying. The Agent decided to use Pan Mill instead of an ordinary mixer which grinds the stones. He wrote a formal letter to the Headquarters seeking their approval for such a change. A week's time was lost in this negotiation and this resulted in complaints from the bricklayers who refused to work unless the quality of the

mortar was improved. This was another incident where matters would have been improved and delays considerably reduced, if the Agent was allowed to take decisions on his own and get the Pan mill from the Plant Hire firm.

Bricks had to be broken into halves for facing walls, which resulted in considerable wastage of bricks and also took more time. The Site Agent decided to get a supply of smaller bricks. This was approved by the Architects.

The Contractors received a telephone call from the suppliers of the pre-cast structural members. The production schedule had been delayed by one week due to difficulties in their firm. Three days later the Contractor received a letter from the suppliers regretting that "owing to unforeseen difficulties, the delivery date could not be met". The Site Agent was very perturbed. It was already explained to the suppliers that the erection of the pre-cast columns was the critical event in the programme. Formal letters were written to the Architect and the Head Office explaining the situation.

At about this time the large central heating boilers were delivered to the site. It was found that owing to a draughtsman's error, the brief bases for the boilers had been made too small, and there was a delay of a few days while the bases were demolished and then rebuilt. Considerable confusion and delay was caused because of lack of co-ordination and understanding between the Main Contractors and the Plastering sub-contractors. The Plastering sub-contractors

requested the Site Foreman to use the mortar from the pan mill for the first coat if possible. The capacity of the pan mill was enough to supply both the bricklayers and the plasterers. The Site Foreman refused, as he was not sure of the Headquarters reaction to such a request. The matter was finally brought up at the next site meeting. The Main Contractors agreed to such an arrangement.

September 1963:-

In the first week of September labour trouble flared up again. The bricklayers steward reported that "work to rule" was in operation because of the poor bonus earnings. The Site Agent instructed him that normal working should be maintained until an attempt was made to remedy the situation. The Contractor's Work Study Officer and other site staff checked some of the work sheets to try and discover the reasons for the poor bonus results. The next day the bricklayers chargehands were advised that the bonuses had been correctly calculated, but the targets would be revised. On the following day there was a meeting at the site. The spokesman demanded a guaranteed flat rate bonus per hour instead of new bonus targets, but it was pointed out that this was against the Federations agreement and could not be considered. A local area organiser for the Union was contacted and, after investigation, he declared that he was satisfied both with relationships between the Contractor and the tradesmen.

In early September the site ran out of nails. The suppliers were expecting delivery at their local depot later that day from their central depot, but explained that the nails could not be sent to the

site until the next day because of the time needed to unload the delivery and reload it on to the local lorry. The central depot lorry was not allowed to deliver to sites even though in this case 5 cwt. of nails were required.

The Electrical sub-contractors were urged to set up the transformers. The delay in setting up the transformers was holding up the work of Heating and Ventilating Engineers.

October 1963:-

The timber supplier telephoned the Contractor in connection with the provision of timber for floor boarding. The Contractor had ordered 4" x $1\frac{1}{2}$" nominal floor boarding, but the suppliers had now received a preliminary sketch from the Architects which showed the floor boarding to 4" x $1^{7}/16$" finished. The supplier informed the Contractor that $\frac{1}{8}$" is lost in planning both sides, and that if $1^{7}/16$" finished timber is definitely required, then the timber used would have to be 4" x $1\frac{3}{4}$". This would cost the Client approximately 8% more. The Contractor raised the question with the Architects at a site meeting the following day and after investigation the problem was resolved by using the timber originally ordered. The timber supplier was asked to send the best consistent finished size that he could manage. Some time was wasted later in sorting out the loads of timber, most of which measured $1^{7}/16$" but with the occasional load of $1\frac{3}{8}$". The finishing trades were already moving on to the site. The Site agent asked the Heating Engineers to speed up the provision

of heating to at least a part of the building so that the finishing trades would start work. The Heating Engineers complained that they could not do anything further unless the Electrical Engineer set up the transformer, as far as they were concerned they had finished their part of the work.

This was brought up at the next meeting at the site. The Electrical Engineer was asked by the Contractors about the delay in setting up the transformers. The Electrical Engineers explained that they had already ordered the transformers and it was due last month but in the meantime the Clients changed their mind and decided to use the same transformer for another building which was going to be built in the near future. This meant that the specifications of the transformer had to be changed. The Electrical Engineer could not give any particular date for the delivery of the transformer.

The pre-cast units delivered to site were found to be arriving in the wrong order. Confusion was caused by the supplier having a different specification in the delivery schedule provided. The Contractor asked the suppliers for the delivery schedule to be corrected so that the subsequent delivery could be made in correct order.

November 1963:-

The Head Office of the Contractor told the Site Agent that as they are coming to the finishing stage it would be advisable to hold more frequent meetings.

The roofing contractors put forward a revised specification for the method of roof construction. This was considered by the Architects but finally rejected because it meant higher costs. The decision was recorded in the minutes at the site meeting held early in November.

No site visits were made after this but the author kept in touch with the progress made on this project. The Contract was completed three weeks after the scheduled completion date, although a part of the building was handed over to the clients in time.

3.2 Case Study B

This Case study concerns the construction of a residential block for students. The contract was let on the basis of a selective competitive tender, and was to the value of approximately £800,000. The firm of General Contractors were at this time handling a few other contracts of a comparable nature.

The construction period for this project was planned to be 78 weeks. The involvement in the project started at week 16. Full access to all previous correspondence and records and minutes of site meetings was however afforded to the author. The site was visited regularly for 3 months. Subsequent visits were made frequently to get the progress reports and collect information which was considered relevant for this study. Many of the site meetings and special meetings that were held up to the time of writing this report, were attended. The site meetings were held in the Contractor's office at the site. The Chairman at each meeting was the Architect, who recorded the minutes of the meeting. Copies were distributed to all the parties concerned.

DESCRIPTION OF THE CONSTRUCTION PHASE

Weeks 1-4

The first site meeting was held. The Contractors decided to use a hired crane to assist in the pouring of concrete for the sub-structure walls. The crane was served by two dumper trucks which ferried the concrete between the mixing plant and the crane 'skip'.

The Site Agent explained that this was faster than other methods, because the wall, when being poured, stands isolated from the surrounding ground formation and it is difficult to get the concrete into the top of the shuttering. The Agent also explained that without a crane, the constant dumping and shovelling of the concrete tends to spoil the mix and requires at least one more labourer to be in attendance. The crane owned by the Contractors was the wrong size, but Headquarters insisted that the same crane be used. This controversy was ultimately settled by hiring a crane, but as a result, the pouring of the concrete started a week late.

The suppliers of window frames were nominated.

Weeks 8-13

The Site Agent queried the number and type of structural steel base-plate that had been delivered during that time. After various telephone calls to the suppliers it became clear that the drawings from which the Contractors had scheduled the base-plates were not the same as the ones held by the suppliers. The Sub-contractor who was erecting the structural steelwork had already grouted some of the base-plates, according to the Contractor's drawing. It was discovered that the Architect had issued amended drawings, but had omitted to send the Contractor a copy. The Contractor had planned the structural steel erection programme on the assumption that the Sub-contractor erectors should make a start 3 weeks afterwards. This mix-up over the base-plates and failure by the suppliers to send the cleats and fixing bolts put the Contractor's programme out of gear.

Weeks 13-17

The C.O.W. and the Site Agent examined a recently delivered load of structural steel which was rusty. After discussion the C.O.W. instructed that it was not adequate to paint over the rust, and that the steel would have to be wire-brushed and then painted. Numerous telephone calls passed between the Site Agent and the Steel Suppliers in an attempt to hold a meeting at the site with a representative from the suppliers to discuss this point and also to try and clarify the position concerning slow and wrong deliveries. Letters were written from the Head Office of the Contractors, both to the Architect and the Suppliers to this effect.

The Contractors were asked by the Suppliers of the window frames to provide them with a schedule for delivery of window frames. It was stated by the Site Agent that the tower cranes used for the concreting operation could be used to lift the windows straight to the floor concerned. This would not only save the cost of storage and reduce the possibility of damage, but also save the cost of double handling. The suppliers were provided with the schedule. This gave the exact dates and the specification of the frames required.

Weeks 17-21

It was noted that the labour turnover of carpenters was running at a high level.

The Architect's progress report to the Client at this time referred to the work being two weeks behind programme, but indicated that the time would be regained where the more repetitive areas of

the building came under construction as the programme allowed for this flexibility. The programme referred to was a very broadly based bar chart which differentiated between the Contractors and Sub-contractors stem of work. The Site Agent complained that he was not consulted during the initial preparation of programme. He also suggested that quite a few improvements could have been made in the present construction programme.

The Contractors complained to the Architects regarding the non-availability of the specifications for the staircases. They could not pre-fabricate staircases in time, so that they could be lifted floor by floor. This meant

a) Stairs could not be provided for the labourers and open ladders had to be used instead.

b) Space had to be left to lift the prefabricated staircase from the ground. This proved to be very uneconomical.

The Site Agent was very critical of the use of table scaffolding for the floor. In his opinion they are very unstable, far too many jacks have to be operated, which makesit very time-consuming.

The Contractors received a telephone call from the suppliers of the window frames. The production schedule had been delayed by one week owing to difficulties with machinery. Three days later the Contractor received a letter from the suppliers regretting that "owing to unforeseen difficulties, the delivery date could not be met". No estimate of the possible length of the delay was given.

The Contractor telephoned the window suppliers about this latest development. The Contractor, who had already placed the scaffolding in position, informed the other Sub-contractors who were to follow the window fixing of the latest position.

Letters passed between the Contractor and the Architect for two weeks. The Contractor outlined the seriousness of the disruption to his programme and the high costs involved in keeping scaffolding idle, and indicated that he might well be forced to apply for an extension of time. The Architects replied that the consequence of any disruptions were purely a matter for settlement between the Contractor and the suppliers. A further letter from the Contractor stated that, having taken all practical steps to ensure delivery, he could not accept that is was a matter for settlement between himself as the Contractor, and the suppliers.

Weeks 21-25

The second crane for pouring concrete arrived, after being cancelled the previous day. Once again the crane was not quitebig enough. The Site Agent explained that though he gave all the particulars of the crane needed for the site the Headquarters ordered the wrong one.

A special meeting was held between the Contractor, Architect, Quantity Surveyor, Structural Steel Suppliers and Structural Steel Erectors. The meeting was called by the Architect, at the request of the Site Agent, to clarify the past problems of scheduling, delivery

and the erection of structural steel and to reach agreement by all parties on future arrangements. The main conclusions reached were that the supplier would in future make every effort to keep to the programme of delivery dates drawn up by the Contractor and that, if practical, a delivery note would be posted direct to the Site to warn of a load in transit. The Suppliers also agreed that any inconvenience caused to the erectors by way of double handling or standing time would be paid for by his company.

The Site Agent was also concerned that the rate of concrete pouring was less than half the rate that the mixer set-up was capable of producing. This was due to the shortage of labour (Carpenters). The rate at which formwork was being erected was governing the rate of pour.

The Consulting Electrical Engineer called for a statement from the Client of his electrical requirements, so that the Electricity Board had ample time to supply a suitable transformer.

The Site Agent decided to pump up the floor screeds instead of using the vertical hoist. A request was placed through the Head Office to the plant hire firm for a suitable pump. The Project Manager on his site visits discussed this with the Site Manager and decided in favour of such an arrangement.

Weeks 25-29

The Contractor reported that there were discrepancies in some of the bending schedules, and that one re-issued schedule had not had

the amendment number added. Consequently the wrong one had been sent to a supplier. The Consulting Engineer agreed to check that all schedules were complete.

The progress of work was discussed in the Site Meetings. It was agreed by the Contractor and the Architect to draw a new construction programme, taking into account the latest work situation. They also discussed the Contractor's claim for extra payment in respect of the overtime and extra labour costs involved in catching up some of the time lost earlier in the contract as a result of events which were outside his control.

Weeks 29-33

The Plumbing Sub-contractor asked for more information on the sanitary and waste installations, since the isometric sketches were insufficient. The Architect reminded the Sub-contractor that he had stated at the beginning of the job that his firm were experts and would need only isometrics. The Architect regretted that the Sub-contractors' statements had not been put into writing at the time.

Due to labour trouble the supply of pre-cast panels was delayed. The Site Agent rang up the supplier, but he could not get any definite date of delivery. This meant that one crane was completely idle. The Architect promised to contact the suppliers and do his best to get the panels at the site as quickly as possible.

The Site Agent complained about the drawings. There was no standard method of putting the instructions and this meant a great

deal of searching and sorting, to get the desired information. The Contractors decided to bring this matter up in the next Site Meeting.

Weeks 33-37

Difficulties in recruiting and maintaining labour were becoming more acute. It was noted that the labour turnover of Carpenters was running at a level equivalent to a "half life" of less than 4 weeks. This meant that only half of the original batch of carpenters were left after 4 weeks. Regarding the shortage of general labour, the Site Agent got over the difficulty by recruiting labour at the site office.

One of the concrete mixers was out of order. The Site Agent rang the plant maintenance department. In spite of frantic telephone calls from the Site the plant maintenance department took 3 days to repair a minor fault in the mixer.

The Site Agent also had to deal with the problem of a lorry driver sent to the site by the Structural Steel Suppliers to collect surplus material. A check showed that although there were about 100 beams surplus to immediate requirements it was not clear how many would be needed for later blocks. After contacting the supplier it was decided to send the lorry away empty, and to clarify the position before the next load arrived. Any surplus material would be taken away at that time.

The site was not visited after the 37th week, because the author got involved after this stage with the second phase of the study. The Site Manager informed later on that although there were many hazards

during the construction process the building was handed over to the Clients just two weeks after the accepted completion date.

CHAPTER 4

SALIENT POINTS FROM CASE STUDIES

In Chapter 3, examples of incidents drawn from the case studies have been described in considerable detail. The impression of confusion, delay, error and conflict gained from the studies, is by no means a false one, nor is it untypical. In the beginning it was decided to select those projects which seemed likely to go reasonably well, to study good building practice so as to gain knowledge of the essentials of building operations from which to create the "model". However it has been confirmed that the practice that is described earlier is normal, and that the contracts described were regarded as "good" by the people concerned. While people regard this as good it is solely on a comparative basis from their past experience, but they do not meet the conception of a satisfactory management process and that we are unable to use them as reliable models but as a basis for an analysis of the operational control of the building process.

In the case studies described, each time a decision was taken at any level, it set in a train of consequences. The timing and level of the decision had a marked effect on the progress of the work at the site. In many instances the delays could have been avoided or at least reduced if decision was taken at right time and by the right person. The causes of delays which the author came across during his stay at the site, and from the existing records could be classified under the

following headings:-

1) Information about work to be done

This included the following

a) Lack of information and uncertainty of town planning authorities

b) Clients uncertain of their final needs

c) Shortage of drawings

d) Late arrival of drawings

e) Drawings not always clear

f) Men on site do not understand incentive schemes

2) Organisation of work- Including use of Plant

This included

a) Bad communication between the different members of the building team

b) Working conditions on the site

c) Job executed in wrong order

d) Poor utilisation of the plant

e) Improper storage of material on site

f) Mechnical breakdowns, wrong plants etc.

3) Delivery of Materials

a) Late arrival of material

b) Material not available (those which have been specified)

c) Materials specified wrong

4) Labour

a) Unavailability of labour

b) Labour disputes and strikes

5) Inclement weather conditions

In the description of the case studies no attempt has been made to represent the delays in quantitative form. The difficulty of suitable scales of measurement is well illustrated by the problem of trying to put a figure to consequential effects of a delay. A job takes longer than was planned - but how realistic was the plan? The next job starts late, but what scope had been provided for replanning to minimise the effect? If replanning had been done, would shortage of materials, incomplete specifications and wrong plant have been revealed when it would otherwise have gone undetected? It is difficulties of this sort, which would have made it inappropriate to report the case study material in a quantitative form. Any quantitative measure of the effect of an incident would have been subject to a host of conditional statements and assumptions.

It is clear from the case studies that there is a factor of uncertainty. Uncertainty about the availability of materials and labour upset any attempt to plan an orderly flow of work. Late, faulty, and misinterpreted information are other sources of uncertainty.

The persistence in unreal assumptions of certainty about the construction process could often lead to uncritical and inappropriate applications of techniques of scientific management. This can be seen particularly in some applications of network analysis where a critical path or other technique based on precise time estimation is applied. The same can also be true of detail bar chart applications. In most of the sites visited the time for revising the bar charts was usually monthly or fortnightly, but even in such short-time planning we have to see such techniques working as true planning tools. Usually, they are abandoned in the face of uncertain circumstances encountered. In most cases they are kept up to date after the event as a form of record. It is worthwhile to mention here that out of 70 sites which were visited during the course of this study, all the sites were using bar charts except one where critical path method was used for programming. None of these sites could use the programme as an effective method of planning and control. All these techniques assume a level of accuracy in anticipating uncertain future events that cannot be realised in practice and which is beyond the capacity of updating to contain within the recognisable boundaries of the original plan. The situation becomes even more complicated when the Site Manager is not even consulted or not given the chance to participate in the original preparation of the programme. This not only results in an unrealistic programme but a programme which in many cases is not acceptable to the man who is responsible to carry it out, i.e. the Site Manager. This will be discussed in greater detail later.

In spite of these one is however impressed by the fact that the construction projects in which either the original programme has been completely abandoned due to uncertainty or has been updated so many times that nothing of the original plan exists, have not lagged behind to anything like the extent that such techniques would suggest they should. This situation has been brought about by the use of crisis management or unscientific management techniques. These practices call for a day to day, almost hour to hour, redeployment of work and resources on site by a constant stream of decisions which are taken by the Site Manager who in this way, keeps the job going without undue delay. Here it is not being suggested that the unscientific management practices are most appropriate at the building sites, on the contrary they have many disadvantages. It reduces the time scale of planning and makes the Site Manager suspicious of the utility of any long term planning. The Site Manager becomes unwilling to accept any form of planning that is not short term, open and completely flexible. One must accept at this stage the existence of uncertainty in the building process and consequently the necessity of informal or unscientific management practices. This makes it all the more important to study the decision-making mechanism at the building site. Nothing has been mentioned in the available literature so far about the responsibilities of a Site Manager, or the authorities that are delgated to him.

Attempts have been made by several Research Workers and Research Committees[1] to assess the duties of the Site Managers. These studies are one-sided and based upon managements' attitudes to what they expect of the Site Managers, and are not a realistic study of the pattern of management which exists on the building sites. With this view in mind it was decided to make a further study of the duties and responsibilities of the Site Managers from the Site management's point of view and to make a realistic study of the authority which ought to be delegated to the Site Managers so they could be more useful in the type of management which exists at the building site. There tends to be a difference of opinion between site and higher management. For instance, as to the exact scope of responsibility, consequently too detailed an approach could well lead to difficulties in grouping and analysis and a simpler form of analysis is essential.

Figure 5 gives a model of project management, it is clear that the Site Manager plays a very important role of a decision-maker and a co-ordinator at the site. He forms the co-ordinator between the site and the other external systems which are linked with the site, e.g. the Architect, Material Suppliers, Sub-contractors etc. etc. These external systems which are beyond the control of the Site Manager are at times responsible for the uncertainties

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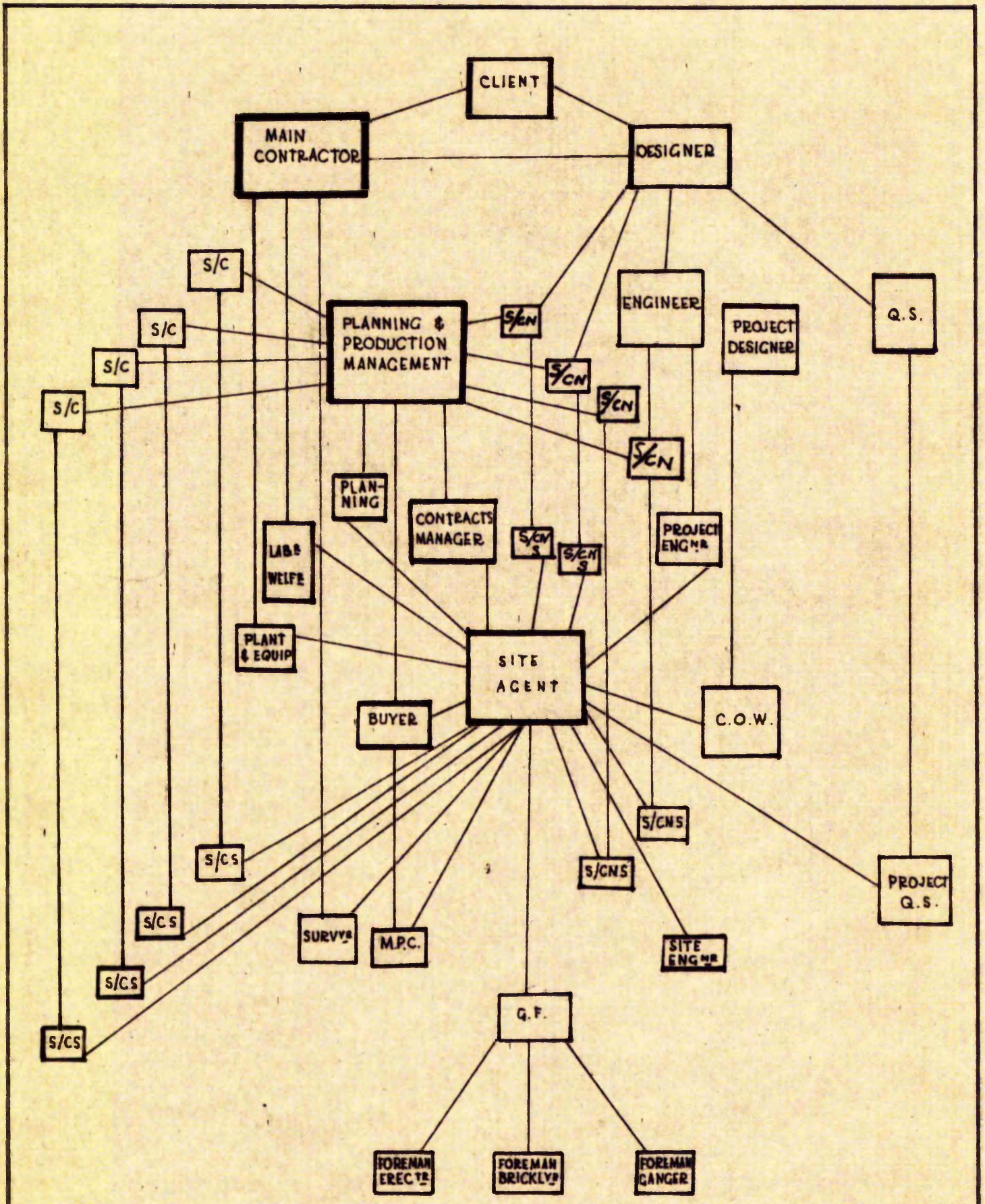
(1) "Construction Management in Building, Present and Future" I.O.B. Report "Functions of Supervision in the Building Industry by



PROJECT MANAGEMENT

FIGURE Nº 5.

which affect the progress at the site, and results in the pattern crisis management which seems to exist at the building sites. One can, however, visualise clearly how a site manager has to work in such circumstances. His main job is that of a decision-maker He has to take a constant stream of decisions to overcome the crisis and also to avoid any forthcoming crisis. This brings one to the importance of authority, which a Site Manager must possess, so that not only he can take decisions but also execute them. Thus, any study of the operational control of building sites necessitates a study of the pattern of the distribution of control.

The example of the incidents which have been described in considerable detail earlier and from the interviews of Site Managers a list of ten authorities were chosen (given below) for a detailed discussion and analysis.

(a) Authority to call for materials.

(b) Authority to negotiate interpretation of drawings.

(c) Authority to call for type of plant.

(d) Authority to recruit men on site.

(e) Authority to discharge men on site.

(f) Authority to negotiate with union on 'bonus rates'.

(g) Authority to negotiate with union on 'welfare conditions'.

(h) Authority to negotiate with union on disputes.

(i) Authority to be present during initial preparation of programme.

(j) Authority to negotiate with sub-contractors.

Measures were taken to make sure that these ten headings take into account all authorities which are of any consequence to the Site Managers. A series of interviews were carried out and also a check was introduced in the experiment which is described later. The list could be confirmed from the study of the delays which occurred at the two building sites discussed earlier. It appears that approximately 65% of the delays were accounted for by lack of information or improper planning at the site level. This meant that the Site Manager had to get the necessary information from the external systems so that he could take proper decisions regarding the redeployment of the available resources or otherwise he had to make the resources available at the site. In many instances the Site Manager could not execute his decisions because of the lack of delegated authority and the formality of communication system between the Site and the Headquarters. This resulted in increased delay of the building operations at the Site.

The above discussion makes it clear that to study the activities at the building site one has to study the authorities which are delegated to the Site Manager in relation to Headquarters.

It also dictates that it is not enough to study the delegated authority, but also their priorities, which reflects to a certain extent the problems which are most often faced by the Site Manager.

In the next few Chapters the factors mentioned have been amplified so as to determine the exact scope of responsibilities of the Site Manager and an attempt has been made to analyse them in a way that it makes it possible to develop indices which not only measure the delegated authority but also the exercised authority by the Site Manager.

CHAPTER 5

RANK ANALYSIS OF DELEGATED AUTHORITY

In the previous Chapter, the authorities which should be delegated to the full-time site supervisor so that he can run his site properly and efficiently have been discussed. It is clear that to measure the delegated authority to the Site Manager and its distribution between the site and Head Office, it is not only important to find out the type of authority to be considered, but it is also essential to establish some index of rating, to get the order of priorities. The ten authorities which should be delegated to the full-time Site Manager are:-

(a) Authority to call for materials

(b) Authority to negotiate interpretation of drawings

(c) Authority to call for the type of plant

(d) Authority to recruit men on site

(e) Authority to discharge men on site

(f) Authority to negotiate with union on "bonus rates"

(g) Authority to negotiate with union on "welfare conditions"

(h) Authority to negotiate with union on disputes

(i) Authority to be present during initial preparation of programme

(j) Authority to negotiate with sub-contractors

RANKING EXPERIMENT

5.1 This Chapter describes in considerable detail the study which was undertaken to establish the rating of these ten authorities mentioned above, and also the qualitative analysis which was carried out, which gives statistical validity to the established ratings. To find out whether there is a general agreement between the site managers regarding the order of importance which they give to the above mentioned authorities and to find out whether the list given is exhaustive, a method of rank-analysis was used. This is described in the next paragraphs.

Twenty-six Site Managers took part in this study. They formed a part of the original sample of 97 firms who agreed to co-operate in the Research work. The site visits lasted from one to two hours. These interviews which were of the non-directive type were used for the compilation of the questionnaire which was used for an attitude analysis described later. A list of the firms who took part in this study is given earlier.

Ten cards printed with the ten headings mentioned earlier were given to the Site Managers. They were also given some blank cards. They were then asked to put the cards in rank of importance. It was made clear to them that if they were to be put in charge of a site and could have certain of these responsibilities, while the remainder would be exercised by the visiting managers, then which of these would be considered the most important to retain, putting

them in order of preference. The advantages of giving them ten printed cards rather than a list of ten headings are as follows:-

1) It is much more interesting for them to handle and re-arrange these cards as they wish than to make marks on a single printed page.

2) There was no bias introduced by giving them a list in a certain order, since the order of the pack on first presentation was always varied.

The reason for giving the blank cards was to give them the opportunity of putting any factor which was missing in the initial list of ten on one of the blanks. This was carefully explained to the Site Managers during the preliminary interview. But in none of the 26 cases was any new entry made. This is ample reason to assume that the list of ten was quite exhaustive. The cards were lettered a,b,c,d,e,f,g,h,i,j, at the back. The same combinations of letters and authority headings were used as given earlier, i.e. the card with "Authority to call for materials" printed on it had 'a' at the back of it.

The ranks, as put down by the Site Managers, were noted. Thus, if the Site Manager put down "Authority to call for materials" as first choice and "Authority to be present during initial preparation of Programme" as second and so on, this was noted down as 'a', 'i' etc. While the subject was rearranging the cards it enabled the author to ask him why he put the cards in a certain order and this

usually was the start of the non-directive interview and brought forward many spontaneous comments from the Site Managers regarding their work situations.

Table App.1 gives the results of the above study. As there are 10 cards, the ranks are from 1 to 10. The table gives the reference number of the sites, and the ranks given by the Site Managers. Say, if the Site Manager at a particular site puts the card printed "Authority to call for Materials" third from the top, 3 was put in front of 'a' and so on.

5.2 ANALYSIS In the Table there are 26 independent judges (i.e. the 26 Site Managers) the number of items they are ranking is ten. The first thing to be found out is whether there is a significant measure of agreement between the judges as a whole or in other words the communality of judgements between 26 independent observers. So the hypothesis to be tested is "There is general agreement between the Site Managers in the building industry regarding the authorities needed to run a building site efficiently".

Here the tools of non-parametric statistics come in very useful, since the measurements are being taken on a ordinal scale and statistics for continuous variates cannot be used.

To test the above hypothesis Kendall's coefficient of concordance was used which is given by

$$W = \frac{12\,S}{m^2\,(n^3-n)} = 0.59$$

where m = number of judges. In this particular case it is the number of site managers who took part in the study = 26

n = number of items which were ranked = 10

S = the sum of squared differences between observed and expected rank totals.

The Table No. 3 gives the details of the breakdown.

Table giving details for calculating of 'χ^2' for testing the significance of general agreement between Site Managers.

No.	Authority Factors	$\sum_{1}^{26}$ (of the corresponding factor) 1	d = (1-143)	d^2
1	a	101	-42	1764
2	b	64	-79	6241
3	c	128	-15	225
4	d	129	-14	196
5	e	166	23	529
6	f	205	62	3844
7	g	221	78	6084
8	h	227	84	7056
9	i	61	-82	6724
10	j	128	-15	225
Total		1429		32888

$S = d^2 = 32888$

$m = 26$

$n = 10$

TABLE NO. 3

For S

It can be shown[1] that for n = 26 the significance of W can be determined from the conversion to χ^2 - distribution,

$$\chi^2 = m\,(n-1)\,W$$

for (n-1) degrees of freedom

therefore $\chi^2 = 10\,(26-1)\,0.59$

$= 138$

and degrees of freedom = $= 10-1$

$= 9$

for = 9

P (significance level)	χ^2
.01	21.7
.001	27.9

From χ^2 - distribution table

In this particular case $\chi^2 = 138$ thus the significance is overwhelming.

Remarks

5.3 The following conclusions can be drawn from this statistical analysis of the data in Table Appendix 1.

a) It can be asserted with absolute confidence that there is

[1] Rank correlation methods - by M. G. Kendall, Chapters 6 and 7.

a high degree of agreement between the site managers in their preference of authorities that they need to run a site efficiently. This agreement could not have arisen by chance and this judgment is a result of their long experience in the building industry. This result could be confirmed from Table 2 in Appendix, which gives the correlation matrix (26 x 26) of the ranks given by each pair of judges out of 26 site managers to the 10 different site authorities. This table was obtained from App. Table 1 by finding the correlation coefficient between each two columns. For this Spearman's rank correlation coefficient was used.

Spearman's rank correlation coefficient

$$\rho = 1 - \frac{6d^2}{m^3 - m}$$

where d = difference in ranks given by the two judges under consideration

m = number of item = 10

So in this case

$$\rho = 1 - \frac{6d^2}{990}$$

and there would be (26 x 26) correlation coefficients. It is clear from the table that the number of statistically significant values of 'ρ' are considerable. This is a further proof of the hypothesis.

b) The first two items are of great interest. The first item which deals with the "Authority to be present during initial preparation of programme" is concerned with the planning state. The second item concerns "Authority to negotiate interpretation of drawings" and as such determines the manager's authority to deal directly with any situation concerning information to site, from which stems site planning.

c) There is a pattern of concordant opinion within the building industry which would suggest a basis for action where inefficiency may be suspected and also how problems may be approached.

Having established that there is a significant measure of agreement between the site managers, one is at liberty to estimate a "true ranking" which is based on the combined estimates of the judges. To do this the obvious method of ranking the items would be to rank them in order of rank totals. Final rating of items was chosen as

No.	Authority	Rating
1	a	7 8
2	b	8 9
3	c	6
4	d	5
5	e	4
6	f	2
7	g	2
8	h	2
9	i	10
10	j	6

TABLE NO. 4

CHAPTER 6

INDEX OF DELEGATED AND ASSUMED AUTHORITY

In the previous Chapter the ten different authorities which the Site Managers would like to have, in order to run their sites effectively have been discussed. It has been made quite clear that the ten different headings discussed earlier, were agreed by the Site Managers themselves to be exhaustive, since no Site Manager suggested any additions to the list. To develop a model of the building site dealing with site control, it is essential to establish some kind of index, to measure the extent of the authority which is delegated to the full-time Site Manager, and how much of it is retained by the headquarters of the firm. This Chapter deals with the establishment of such an index, and an attempt has been made to measure the extent of "authority which is actually exercised by the Site Manager".

It is clear from the previous Chapter that the ten authorities are not equally important and as such some kind of rating must be used to calculate the above mentioned indices. The obvious solution would be to use the ratings derived from the ranking study. Therefore, to deal with such indices the tools of non-parametric statistics were used again. When the measurements are taken on an ordinal scale it is extremely difficult to say how much more important one factor is than another. For example, in this particular case one cannot say that

"authority to interpret drawings" is 8 times more important than "authority to deal with Trade Unions." In order to discover whether the ratings are being distorted a smaller sample of ten sites was chosen and tested with different ratings. This is mentioned elsewhere. Two questionnaires were designed for the establishment of the indices. The ten items of authorities discussed in the previous Chapter were included in this questionnaire.

6.1 INDEX OF DELEGATED AUTHORITY

The first questionnaire was designed so as to measure the extent of authority which was delegated to the Site Manager and the Index was called the "Index of Delegated Authority". The form of the questionnaire is shown in Appendix 1a. The ten headings were further subdivided to get a more exact picture of the distribution of authorities between Headquarters and the site level.

The authorities which deal with making plant and materials available at the site have been subdivided, so as to ascertain whether the Site Manager had the authority to go straight to the Plant Hire Firm or the suppliers when plant and materials were required, or whether he had to go through the headquarters of the firm. In the detailed case studies it has been shown that incidents have arisen where considerable time could have been saved by going stright to the suppliers, rather than asking headquarters to take appropriate action. If the Site Manager had the authority to go straight to

the suppliers for calling forward materials, the extent of delegated authority was rated as 7. In the case of the Site Manager having to go through the headquarters it was rated as 3. In the case of plant, if the Site Manager could go straight to the Plant Hire Firm, it was rated as 6, but in case he had to apply to the headquarters of the firm it was rated as 3. This means that if the Site Manager was given full authority to deal with the suppliers, whenever a materials shortage occurred at the site the delegated authority got the full rating of 7, allocated for authority dealing with the "calling forward of materials."

In the case of authorities dealing with recruitment and discharge of men, the differences were limited to a choice of three headings

(1) Absolute

(2) Limited

(3) None

The subdivided ratings in the case of "authority to recruit men" were 5, 2, 0, depending on whether the Site Manager had complete, limited or no authority to recruit men at the site. Thus, if the Site Manager of a particular site had no authority to do this, in cases of labour shortage, without prior consultation with the head office, the extent of delegated authority was rated as 0. If he could recruit a certain number of men without consulting the head office, it was rated as 2, and if the Site Manager had complete freedom to appoint men on his site it was rated as 5. Similarly the subdivided ratings

for "authority to discharge men" were 4, 2, 0.

The authorities dealing with labour relations and union matters (f, g, h) were also subdivided to a choice of three headings

(1) Absolute

(2) Limited

(3) None

The subdivided ratings were 2, 1, 0, so if the Site Manager had no authority to deal with union matters, it was rated as 0. If he had limited authority he gets 1 and if he had absolute authority he was rated as 2.

In the case of (i) which deals with the "authority to be present during initial preparation of programme" the actual fraction of time spent in the preparation of the programme was to be given, so there were six subdivided headings. As the total rating was 10 the actual fraction (0, 2, 4, 6, 10) is the subdivided rating.

The authority dealing with the "interpretation of drawings" (b) has been subdivided to find out whether the Site Manager could go straight to the Architect or whether he had to go through the headquarters of the firm. The subdivided ratings were 8 and 3 depending upon whether he could go straight to the Architect or if he had to extract the desired information through headquarters.

If the subdivided headings were lettered as (a_1, a_2) and (b_1, b_2) etc. where a, b, c, etc. represents the main headings, the Table No.5 gives the table of the subdivided ratings.

SUBDIVIDED RATINGS

Main Authority	Total Ratings	Subdivided headings with the ratings					
a	7	a_1 7	a_2 3				
b	8	b_1 8	b_2 3				
c	6	c_1 6	c_2 6				
d	5	d_1 5	d_2 2	d_3 0			
e	4	e_1 4	e_2 2	e_3 0			
f	2	f_1 2	f_2 1	f_3 0			
g	2	g_1 2	g_2 1	g_3 0			
h	2	h_1 2	h_2 1	h_3 0			
i	10	i_1 10	i_2 8	i_3 6	i_4 4	i_5 2	i_6 0
j	8	j_1 8	j_2 6	j_3 4	j_4 0		

TABLE NO. 5

The final form of the questionnaire is given in Appendix No. 1a. and it includes all the items with the subdivisions discussed earlier. The questionnaire was designed to be filled in by the Project Manager or the representative from Headquarters. The total of rating score was taken as a measure of the "delegated authority to the site". This score is a measure of the extent of authority which was delegated or thought to be delegated to the Site Manager for carrying out his responsibilities as such.

To find out the existing position on the building sites which were being investigated, the questionnaires were sent to the persons concerned. The questionnaires were either sent by post, with a covering letter explaining the purpose of the study, and in those cases where visits were made to the sites soon after the compilation of the questionnaires, they were completed during the course of the site visits. Where the Project Managers were not present at the site the questionnaires were sent to the headquarters. The Project Managers or the representative of head office were asked to indicate the proper subdivided classification. The scores for every firm were recorded and Table No. 3a in the appendix gives the results.

Table No. 3a is a Matrix of (69 x 10). The horizontal rows give the reference number of the projects, and the columns give the different classifications of the authority. The scores on this Table give the extent of the authority which is delegated to the Site Manager by the Head Office. Thus, for example, if the score under

column (b) of a particular project is 8, it means that the Site Manager is authorised to go straight to the Architects in the case of any queries which arise from the drawings or instructions provided on the site. The last column, which gives the sum total of the rows, represents the Index of Delegated Site Authority.

The maximum value of the Index of Delegated Authority (say I_1) can be (10+8+7+6+6+5+4+2+2+2) = 52 i.e. the sum total of the ratings. The range of I_1 for the above sample of 69 building sites varies from 14 to 52.

6.2 INDEX OF ASSUMED AUTHORITY

The next questionnaire was designed to establish an Index for the measurements of authority which the Site Manager actually exercised. One can argue that the head office may delegate the authority, but there may be confusion in the minds of the Site Managers, as to the actual control they can exercise. To find out the exact distribution of Control between headquarters and the site level it is not enough to know the Index of delegated authority, but also the control actually exercised by the Site Manager. This meant, that one has to find out from the Site Managers themselves how frequently they utilised the delegated authority for decision making and operational control at the site. The questionnaire given in Appendix No. 1b was designed for the evaluation of such an index.

The questionnaire was based on the same ten headings mentioned earlier in the Chapter. The headings were further subdivided, to find out how frequently the Site Managers had to exercise the authorities.

The subdivided headings were

1. Frequently
2. Seldom
3. Never

Same ratings as used for the computation of the "Index of Delegated Authority" were used again.

The questionnaires were filled in by the Site Managers during site visits. If the site had already been visited, the questionnaires were sent by post. The Site Managers were asked to put a circle round the sub-headings which they thought nearest the actual conditions at that particular site. Thus, if the Site Managers put a circle round "frequently" under the item "calling for plant direct from Plant Hire Firms", it meant that quite frequently he had to exercise that authority. In the second questionnaire, the item dealing with "the discharge of men" was omitted; in this case the ratings obtained from the item for "the recruitment of men" was used. A total of 61 Site Managers filled up the questionnaire.

Table No. 3b in the Appendix gives a Matrix of (61 x 10). The horizontal rows of the table give the reference number of the project,

and the columns give the different classification of authorities. The scores on this Table give a measure of the different authorities actually exercised by the Site Manager. The last column which gives the sum total of the rows represents the "Index of exercised authority" of the different sites. This index will be referred to as I_2.

6.3 COMMENTS ON I_1 AND I_2

(1) The range of I_1 is from 14 to 52. The Fig. 6 gives the distribution of project by I_1. I_1 is greater than 35 in 42 projects out of 69 projects. Which shows that there is growing realisation among the firms to decentralise the control. The sites are being given considerable freedom to decide on their course of action.

(2) Table 6 gives the two-way classification of contract value of projects as against I_1.

Contract Value	<30	$30<40$	>40
<£150,000	12	14	7
>£150,000	4	16	15

TABLE NO. 6

The X^2 test was performed on the above Table. The X^2 value of 6.90 with 2 degrees of freedom is significant at more than 5% level. This suggests that there is significant association between the contract value and I_1. It appears therefore that firms tend to

delegate more control to the site level in bigger contracts. No such association was found to exist between I_1 and building type or method of contract selection.

(3) The correlation coefficient between the indices I_1 and I_2 is 0.731 (Spearman's correlation coefficient). This means that 't' value

$$= 0.731\sqrt{\frac{(54-2)}{(1-.731^2)}}$$

since 54 contracts were compared

't' = 7.71

This value of 't' with 54 degrees of freedom is significant at 0.5% level. This suggests that the general boundaries of delegated authority between central management and site management were usually recognised. It is noteworthy though that except in two cases where I_2 was greater than I_1 the index I_1 was consistently greater than I_2. This suggests that site management was exercising a lesser degree of control that they were expected to.

(4) It is significant that 30 out of 68 Site Managers had no part in the preparation of the construction programme and only one in twelve reported full participation.

(5) Nine Site Managers out of 68 had complete authority to deal with Union matters, but in most cases partial control was exercised from the site, but this was not resented by the Site Manager.

(6) From information gained concerning the responsibility

delegated to the man-in-charge on site it appeared possible to apply a method of classification by rank order. In order to discover whether the ratings were being distorted a smaller sample of 10 sites was chosen and ratings valued from 20 to 10 but this did not bring any significant changes in the ranking order.

(7) The detailed survey of the existing position on the building sites of delegated authority and assumed authority is given as mentioned in Appendix Tables 3a and 3b.

CHAPTER 7

QUESTIONNAIRE FOR ATTITUDE ANALYSIS

7.1 PROCEDURE USED FOR FRAMING THE QUESTIONNAIRE

This Chapter deals with the framing of the questionnaire (mentioned earlier in Chapter 2) to find out the attitude of the Site Managers on the interrelationships in the model of Building Site activity. From Fig. 5 it is quite clear that the Site Manager holds a very central position in the project administration. Attempts have been made by Research Workers(1)(2) to study the work pattern of Site Managers, but it was during study of the site activity and the study of the pattern of distribution of control vested on the site in decision-making mechanism that it became quite apparent that the recording and analysis of observable behaviour of Site Managers gives only a part of the picture; what they felt and believed is no less important than what they were observed to be doing with this in mind, a questionnaire was framed to systematically study the attitudes of the Site Manager.

It could be suggested that excessive attention is being given to the analysis of subjective opinions of Site Managers but the majority of Site Managers included in the sample had over 10 years experience in that position and were well acquainted with the

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(1) C. Reynaud - A Study of Site Manager. An unpublished thesis.

(2) Functions of supervisors in the Building Industry. By Hans Wirdenius and Sterner Lonnsjo.

problems of effective control on the site. Fig. No. 9 gives the distribution of Site Managers by type of Technical education. It is quite clear that although a very small fraction had formal education but the very fact that they had been working on an average of ten years as full-time site supervisors, they had extensive knowledge of the problem of the site management.

The First Attitude Survey

The objective and disinterested recording of subjective opinions has been developed in industry by psychologists(1)(2) to reveal to the higher management impressions concerning environment likely to affect performance, how these factors interact and how they might possibly be changed or modified to produce desirable improvements on performance.

Two method most frequently used in studying responses consisted of

(a) Questions (put either directly or written questionnaires) apparently admitting of unambiguous replies about the way subject thinks, feels and is disposed to respond towards working conditions; the results are classified under the headings already built into the enquiry, and

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(1) Thurstone, Louis Leon - The Measurement of Values.
(2) Lickert Rensis, Hayes, Samuels P., - Some Applications of Behavioural Sciences.

(b) Non-directive interviews in which interviewer merely records whatever opinions, feelings and requirements relative to the work situations are spontaneously expressed by the subjects, who volunteer both to attend and disclose their opinions.

It is important that all questionnaires, whether verbal or written, must pose specific questions, and their compilers must ensure not only that questions are relevant but also that they are comprehensive in such a way that the answers can be given explicitly.

In this study both the above methods were used. The method of non-directive interview was used to compile the questions. In this the interviewer does not ask questions, except to encourage the subject to explain or to amplify something which has been said spontaneously about the topic. The assumption is made that points raised spontaneously by the subject are for him those features of work situations which are at that particular time are most important. By collecting a large number of replies it is possible to identify those problems which are commonly experienced. The success of non-directive interviews depends, of course, upon the voluntary co-operation of subjects and upon a guarantee that the information offered is both confidential and anonymous. It was realised from the outset

that two important points were to be kept in mind in compiling the questions for the questionnaire

(1) the questions should be of significance to the Site Managers, and

(2) It should include all the relevant points which seem to affect control on sites.

This meant that the questionnaire is compiled as a result of our interview with the Site Manager. As mentioned earlier in Chapter 2 the information from 26 site visits was used for the experiment discussed in Chapter 5. The 26 site visits and consequent interviews with Site Managers in conjunction with the detailed study of two building sites were used for the compilation of the questionnaire. The picture of the problems faced by Site Managers obtained by interview of 26 Site Managers and other members concerned with building sites including the Project Managers and Trades Foremen, seem both clear and intelligible. It certainly suggests in what directions there is room for improvement. The results of these interviews each of which lasted about one hour and which raised on average about four main points of interest, which were

(1) Information and communication

(2) Organisational Management

(3) Training courses in Site Management

(4) Labour welfare and labour relations

The interviews were held at the same time as the Site Managers were taking part in the experiment of ranking study. As the subjects were placing the cards (with headings of authority printed on them) in order, they were asked the reasons for placing the cards in that particular order. This resulted in voluntary discussion of problems concerning work situations. They were encouraged to amplify points which were considered to be relevant.

In spite of all these precautions and preparations, it could hardly be possible to compile questions which were always unambiguous and pertinent to Site Managers. Forthcoming this a preliminary questionnaire was compiled which consisted of 24 questions and was sent to twenty Site Managers who had already been interviewed. Guidance was received from studies which were carried out in The Manchester College of Science and Technology[1][2], and which gave very definite results. Some of the questions, especially under the heading of organisational management, were chosen from these studies. It was found that this preliminary questionnaire still contained ambiguities and therefore needed further modification.

The final questionnaire consisted of 34 questions. The questions under the different headings were placed in random order to remove the possibility of any bias introduced. The questions can be divided into two broad categories.

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[1] M. I. Hussain - Ph.D. Thesis, Discriminant Model for the Analysing of Factors Influencing Innovation in Industry. Jan. 1965.

[2] M. P. Srivastava, Ph.D. Thesis, A Study of Wastage and Sickness. 1959.

(1) Those questions which were concerned with the particular site they were working at the time and have been called 'J' items.

(2) Those questions which are general to the Building Industry and have been called 'B' items.

A number of questions were duplicated in a different form to check the validity of the replies. These 34 questions were printed in four sheets. Although the sheets were numbered 1 to 4 for identification, the questions were not numbered. The 4 sheets were stapled at random to form the questionnaire. The questionnaire is given in Appendix 2.

7.2 SALIENT POINTS NOTED DURING INTERVIEW

The 4 main headings of classification have been described in the following paragraphs. In the next Chapter the validity of qualitative estimates of opinions and attitudes as indicators of probelms at the building site is discussed.

Labour Relations and Welfare

The Site Manager and some of the Project Managers considered that the pay of labourers and Craftsmen was the main source of damage to the image of the building industry, being a serious hinderance to recruitment and retention of competent operatives in the industry. In their opinion an all round improvement in welfare facilities would solve the problem of labour relations at the

building site, and consequently achieving higher productivity. Another Site Manager suggested that the workers are paid far too much for their responsibility. It was found that this comment was reflection on his own salary. On the other hand, a Site Manager insisted strongly that the payment was not the main source of dissatisfaction; it was the hostile relationships that were the main cause of labour troubles at the building site. Another Site Manager suggested that the high labour turnover made if difficult for them to control the site. At one of the sites the labour turnover was 60% in a four week period; this meant that every time a new workman arrived at the site there was a loss of output, because they took several days to get acclimatised themselves to conditions. One or two Site Managers and a few Trades Foreman felt that there should be regular exchange of opinion between the site management and operatives.

Information and Communication

Some of the Site Managers complained that the main cause of trouble on the site is that information is lacking or not available at the right time. They suggested that most of their time was spent in chasing information and they had hardly any time left for future planning. A few Site Managers considered that the Architects ought to be more concerned about the flow of information to the site. They suggested that the drawings and specifications should be standardised.

At one of the building sites visited the Site Manager received 300 drawings when only thirty drawings were needed. A lot of time was spent in sifting and sorting information. This meant that the ordering of materials was delayed by six weeks. One of the Site Managers complained that the Architect often specified materials which were not available or in great shortage.

The case studies also suggest that about 60% of the delays that occurred on the site were either due to wrong information or lack of information.

The Site Managers held very strong views about the usefulness of planning and programming techniques at the building site. Though most of them agreed that it was essential to have a detailed programme, some of them had grave doubts as to the practical implementation of these programmes, due to the very nature of the information flow and the accumulation of so many uncertainties arising in the course of construction process.

Organisational Management

It was soon apparent from the interviews that the basic problems of site control were bound up with the interrelationships between the different members who contribute towards the building process. Some of the Site Managers felt that the performance on their site could have been considerably improved if the central organisation tackled the problems promptly.

Some Site Managers considered that the performance of a particular site depended largely on the extent to which the individual members felt that the nature of the central organisation created and maintained a sense of personal worth. Other Site Managers stressed the need for a kind of organisation structure which takes into account the uncertainties which affect the progress at the different stages of construction.

Training Courses on Site Management

Mixed opinions were expressed by Site Managers on matters dealing with problems of site management. One Site Manager suggested that technology in the building industry is changing so fast that it becomes difficult for them to cope with the situation unless they are sent on short term courses at regular intervals. A few Site Managers expressed views which were contrary to this attitude, in their opinion site management is not a teachable subject. They firmly believe that it is only experience and intuition which makes a good Site Manager. It was felt during the interviews that this is a matter of great concern to all the people concerned with the building industry. One Site Manager said that his whole approach to the problems on the site had become much more rational since he attended a course which was based on case methods.

CHAPTER 8

This Chapter deals with the analysis of the questionnaire described earlier. The statistical methods used to test the validity, as indicators of on-site performance, and to indicate the problems existing on the building site.

The questionnaire was dispatched to 40 Site Managers, from whom 28 completed returns were received before the final analysis was carried out.

8.1 SCORING OF QUESTIONNAIRE

The Site Managers were asked to indicate the opinion they thought accorded with their experience as Site Managers. They were asked whether they

(1) Strongly agreed with

(2) Agreed with

(3) Were undecided about

(4) Disagreed with

(5) Strongly disagreed with

the opinions expressed in each statement. The answers were scored 8, 6, 4, 2, 0 according to order quoted above. In case the statements were framed to represent negative views they were scored the other way round. The answers given by 28 Site Managers are recorded in the rows of the matrix in Table No. 4. (Appendix) in respect of each of the 33 questions.

8.2 ANALYSIS OF VARIANCE OF RESPONSE MATRIX

Before any attempt is made to assess the attitudes of the Site Managers, it is important to test whether the answers (which included alternative methods of expression) for each reply was consistent, thereby indicating it had been completed with forethought and not at random. An analysis of variance was carried out to test the significance of the variances between the sites and between the items.

The 33 items in the questionnaire was sub-divided into two categories

(1) Those items which concerned only individual sites, and will be referred to as 'J' items.

(2) Those items which are generally applicable to the building industry and will be referred to as 'B' items.

The second category was further sub-divided into two classes

(a) Those items which dealt with the largely personal attitudes of the Site Managers to the Building Industry and will be referred to as B_1 items.

(b) Those items which represented the general opinion towards the Building Industry and will be referred to as B_2 items.

The table gives the item numbers and the category into which they fall.

Category		
J	B_1	B_2
4	2	1
5	3	6
10	7	8
12	11	9
17	14	13
18	15	16
27	19	21
28	20	23
29	22	26
31	24	30
	25	
	33	

TABLE NO. 7

The analysis of variance was carried out separately for the different categories

Results of the Analysis of Variance on 'J' Items

Here we want to test whether the variation in the responses by the Site Managers to 'J' items was too great to be accounted for by random variations. The results of the analysis of variance are given in Table 8.

Source of Variation	Sum of Squares	Degrees of Freedom	Estimate of Variance	'F' Value
Between Sites	310	27	11.5	2.05
Between Items	270	8	33.8	6.06
Residual	1206	216	5.6	-

TABLE NO. 8

Analysis of variance of 'J' Items

Between Sites:- The 'F' value of 2.05 with $\nu_1 = 27, \nu_2 = 216$ is significant at more than 0.1% level i.e. the variance between the sites is very highly significant.

Between Items:- The 'F' value of 6.06 with $\nu_1 = 8, \nu_2 = 216$ is significant at more than 0.1% level.

The analysis of variance of the 'J' items suggests that the variations between the sites and between items are very highly significant and this could not have occurred by chance.

Analysis of Variance - 'B1' Items

The Table below gives the results of the analysis of variance on B1 Items.

Source of Variation	Sum of Squares	Degrees of Freedom	Estimate of Variance	'F' Value
Between Sites	280	27	10.37	2.27
Between Items	888	11	80.71	17.73
Residual	1353	297	4.55	-

TABLE NO. 9

Between Sites:- 'F' value of 2.27 for $\nu_1 = 27$ and ν_2 297 is significant at 0.1% level.

Between Items:- 'F' value of 17.73 for $\nu_1 = 11, \nu_2 = 297$ is significant at 0.01% level.

The results of the analysis varianoes on 'B_1' and 'J' items clearly shows that responses of the Site Managers are very highly significant, in other words the varianoes in the responses could not happen due to random variations. This indicates that the questionnaires were completed with forthought.

8.3 CORRELATION MATRIX

The analysis given above clearly shows that the items included in the questionnaire are discriminating in nature i.e. these items could be used to differentiate between the sites, but no further information is provided by the above analysis. It does not, for example, show which of the items are responsible in the main for the variation, or which group of items cause the highest variation. The items in the questionnaire were not independent, in order to determine which items are responsible for the variation and to determine the interdependency of the items, it was found essential to carry out a further analysis.

To test the interdependency between the items, it was decided to calculate the correlation coefficients between the different items and construct a correlation matrix. Since there are 33 items the number of correlation coefficients in the matrix would be 33 x 33 = 1089. They were calculated on the Atlas Computer. The correlation matrix is set out in Table No. 5 in the Appendix.

Table No.10 indicates those items which were found to be significantly correlated. This table is an extract from the correlation matrix set out in the Appendix, Table No. 5.

Item No.	Correlated with Item No.
1	22, 25*
2	19
3	5*, 7, 16, 18, 24, 27
4	5, 7*, 18*, 26*, 17, 29
5	3*, 4, 18*, 27, 29
6	16*, 21, 32
7	3, 4*, 20, 27*, 29*, 30*
8	10, 11*, 18, 21
9	13, 24*
10	8, 18, 24, 29*
11	8*, 17*, 33
12	13, 27
13	9, 12
14	21
15	
16	3, 6*, 18, 19
17	11*
18	3, 4*, 5*, 8, 10, 16, 27*, 29*

TABLE NO. 10

Table continued...

Item No.	Correlated with Item No.
19	2, 16, 30
20	7, 27*
21	6, 8, 14, 22
22	1, 21, 32
23	
24	3, 9*, 10
25	1*, 26, 31, 32
26	4*, 25, 27* 31
27	3, 4, 5, 7*, 12, 18*, 20*, 26*, 29, 21*
28	
29	4, 5, 7*, 10*, 18*, 27
30	7*, 19
31	25, 26, 27*
32	6, 22, 25
33	11

TABLE NO. 10

NB. The asterisk mark in the table signifies those items which are negatively correlated.

Table 10 shows quite clearly that correlation exists in a considerable number of cases.

8.4 COMPONENT ANALYSIS

The analysis of variance shows that the variance of the Response Matrix, when considered between the items and between the sites is significant at 0.1% level. The correlation matrix shows that certain items are significantly correlated. The next step in the analysis will be to determine the items which are responsible for maximum variation and if possible to express the data in terms of fewer than 33 items. This can be achieved by introducing new and uncorrelated variates with as large a variance as possible. In other words to perform a Multivariate analysis of the response matrix.

This was achieved by determining the principal components, and extracting the latent roots of the correlation matrix. The theory involved in this method has been discussed in Appendix 3. There are several methods[1][2] by which the operation can be undertaken but in this particular study Householder's[3] method was used. A programme written in Atlas authocode was used for this purpose. Since the correlation matrix is of the order of (33x33), there must be 33 latent roots, but the programme was developed in such a way that the roots with very small variance are ignored (9 were involved). The Table 11 gives the latent roots.

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(1) M. G. Kendall - Multivariate Analysis.

(2) Richard Bellman - Introduction to Matrix Analysis

(3) A. S. Householder - The Approximate Solution of Matrix Problems. J.Assoc. Comp. Mach. 1958.

The programme used is given in Appendix 4.

No.	Latent Root λ's	Percentage variance
1	6.087	38.503
2	3.815	11.597
3	3.242	9.856
4	2.914	8.859
5	2.508	7.623
6	2.025	6.155
7	1.864	5.667
8	1.751	5.324
9	1.337	4.064
10	1.195	3.632
11	1.014	3.082
12	0.913	2.776
13	0.745	2.264
14	0.644	1.958
15	0.577	1.755
16	0.483	1.467
17	0.382	1.163
18	0.322	0.977
19	0.293	0.891
20	0.242	0.753
21	0.170	0.517
22	0.143	0.433
23	0.120	0.364
24	0.110	0.334

TABLE NO. 11

NB. For the component analysis the scoring of the items have been changed from 0, 2, 4, 6, 8 to 0, 1, 2, 3, 4.

The principal component matrix is set out in Table 6 in the Appendix for the components of the new variates in terms of the original 33 items.

8.5 DETERMINATION OF FACTORS

It is clear from Table 11 that the variance due to the first three "new variates"

$= (\lambda_1 + \lambda_2 + \lambda_3)$ where λ_1 λ_2 and λ_3 are first second and third latent roots

$= (6.087 + 3.815 + 3.242)$

$= 13.144$

and the percentage variance due to these three variates is 39.956. In other words the 33 original items have been transferred into new variates, such that the first three factors account for 39.956% of the total variance.

It is also quite clear from Table 11 that the variance due to fourth, fifth, etc. etc. factors are fairly constant, and so they were not considered as significant factors.

Table 12 gives the major components in terms of the original items, of the first three new factors as obtained from the principal component matrix.

Factor I	Factor II	Factor III
4	6	1
5	8	19
18	11	23
27	17	25
29	21	32

TABLE NO. 12

Factor I:- Is thus identified by the analysis as being strongly loaded into the five items 4, 5, 18, 27 and 29. These are manifestly concerned with matters of site organisation. This factor has been referred to as S.O. Factor.

Factor II:- This factor would be referred to as A-Factor.

Factor III:- This factor would be referred to as L-Factor.

The interpretation of the items included in these factors would be discussed in Chapter 10.

8.6 SIGNIFICANCE OF THE THREE FACTORS

The opinions of the Site Managers have been classified into three separate groups of factors. The methods used to test the level of significance of these factors and the inter-factor significances are discussed below.

	FACTOR I					FACTOR II					FACTOR III				
	4	5	-18	27	29	6	8	-11	17	21	-1	-19	23	25	32
4	.	607	670	571	697	286	-173	-235	-015	096	-055	-206	-133	-207	077
5		.	771	498	503	224	-283	-195	064	-077	338	036	016	068	-031
-18			.	580	681	070	-414	-239	-042	-159	190	045	-077	-176	-170
27				.	597	060	-073	164	174	122	+168	-275	-068	-141	-188
29					.	007	-112	338	180	165	-085	-223	-079	-252	-049
6						.	148	398	284	451	000	199	010	237	409
8							.	427	253	493	085	-097	017	037	-024
-11								.	400	341	076	246	014	061	-115
17									.	359	-026	-007	024	-186	-217
21										.	-114	-295	-143	078	084
-1											.	262	302	482	000
-19												.	096	073	295
23													.	332	360
25														.	431
32															.

TABLE NO. 13

The correlation coefficients between the items included in the three factors have been set out in Table 13, in which the decimal points are omitted.

Negative signs have been used for the items 18, 11, 1 and 19, this is in order to take into account the direction of scoring of the items.

The level of significance of the factors could be determined by using the concordance test.

Factor I:- The sum of the correlation coefficients in the correlation coefficient triangle (Table 13) under Factor I is

$$\sum_{1}^{10} r = 6.175$$

mean correlation coefficient $\bar{r} = 0.6175$.

The coefficient of concordance $W = \bar{r} = 0.6175$.

The significance of 'W' could be tested by conversion to X^2.

$$X^2 = W \times m \times (n-1); \quad \text{here } m = 5 \quad n = 27$$

$$= .6175 \times 5 \times 27 = 83.36$$

The X^2 value of 83.36 with 27 degrees of freedom is significant at more than 0.01% level.

Factor II:- $\sum_{1}^{10} r = 3.554$

$$W = \bar{r} = 0.3554$$

$$\therefore \quad \chi^2 = W \times m \times (n - 1)$$

$$= 0.3554 \times 5 \times 27$$

$$= 47.98$$

The χ^2 value of 47.98 with 27 degrees of freedom is significant at 1% level.

Factor III:-

$$\sum_1^{10} = 2.633$$

$$\bar{r} = W = .2633$$

$$\chi^2 = W \times m \times (n-1)$$

$$= 0.2633 \times 5 \times 27$$

$$= 35.55$$

The χ^2 value of 35.55 with 27 degrees of freedom is significant at about 10% level.

The results of these concordance tests are set out in Table 14. The Table 14 also gives the mean values of the correlation coefficients between the factors. Thus the mean values of correlation coefficients between

Factor I and Factor II = μ_{12} = -0.0027

Factor I and Factor III = μ_{13} = -0.0591

Factor II and Factor III = μ_{23} = -0.0141

	Factor I	Factor II	Factor III
Factor I	Σr = 6.175 W = 0.6175 X^2 = 83.36 P = 0.01%	-0.067 $\mu 12$ = -0.0027 Not significant	-1.477 $\mu 13$ = -0.0591 Not significant
Factor II		Σr = 3.554 W = 0.3554 X^2 = 47.98 P = 1%	-0.353 $\mu 23$ = -0.0141 Not significant
		Factor III	Σr = 2.633 W = 0.2633 X^2 = 35.55 P = 10% level

TABLE NO. 14

In order to test the interfactor significances, t-test was used to show that the μ-values are not significantly different from zero. It was found that none of the values μ_{12}, μ_{13}, and μ_{23} are significantly different from zero. This suggests that the three factors are independent. (It has been proved in the discussion of the theory involved in the extraction of the factors that the new components are uncorrelated).

8.7 PERFORMANCE INDEX P_1

The above results show that the first and second factors are significant at 0.01% level and 1% level respectively. The third factor, although it exists is not highly significant. This could be due to the lack of discriminatory power of the items loaded into the third factor. The results of the analysis of variance * of S.O. factor are given in Table 15.

Source of Variation	Sum of Squares	Degrees of Freedom	Estimate of Variance	F
Between Site Managers	151.4	27	5.61	9.15
Between Items	28.4	4	7.10	11.5
Residual	66.4	108	0.61	-

TABLE NO. 15

*The scoring of items has been changed from 0, 2, 4, 6, 8 to -2, -1, 0, +1, +2 in the analysis of variance.

Between Site Managers:- The 'F' value of 9.15 with $\nu_1 = 27$, $\nu_2 = 108$ is significant at 0.01% level.

Between Items:- The 'F' value of 11.5 with $\nu_1 = 4$, $\nu_2 = 108$ is significant at 0.01% level.

This shows that the Site Managers express consistent opinions within the S.O. Factor and this when taken in conjunction with the fact that the S.O. factor is independent of 'A' and 'L' factors, we can conclude that the Site Manager is most likely judging some actual state of affairs as he sees it. One could regard his attitude towards the job as objective. The S.O. Factor determined above could therefore be used as an index of performance on the building site. The S.O. factor would be referred to in future as Performance Index P_1. The Table 16 gives the P_1 values for the different sites included in the study.

No.	Project Ref. No.	S.O.Factor P_1 - Index	No.	Project Ref. No.	S.O.Factor P_1 - Index
1	P/56	30	15	P/339	30
2	P/11	32	16	P/359	34
3	P/14	22	17	P/467	40
4	P/24	10	18	P/491	6
5	P/28	30	19	P/520	12
6	P/29	22	20	P/527	8
7	P/54	24	21	P/529	16
8	P/6	8	22	P/528	34
9	P/87	38	23	P/36	24
10	P/188	38	24	P/435	20
11	P/198	16	25	P/323	26
12	P/207	24	26	P/456	8
13	P/232	12	27	P/294	8
14	P/290	22	28	P/516	8

TABLE NO. 16

8.8 COMMENTS:-

The problems arising on the building site as seen by the Site Managers could be classified under three distinct headings:-

(1) S.O. Factor

(2) 'A' Factor

(3) 'L' Factor

The factors derived, are responsible for variances in the response matrix, which are in descending order of magnitude. This could be interpreted to mean that the problems arising out of these factors are also in descending order of priority. The factors would be discussed in greater detail in Chapter 10.

CHAPTER 9

OPERATIONAL CONTROL IN RELATION TO "ON SITE" VARIABLE

In an earlier chapter an index was developed to measure the efficiency of site organisation. This index was based on the subjective evaluation of the site managers. Attention is now turned towards studying the process of operation control on the building sites in relation to the "on site" variables, such as labour input, materials input, etc. In this chapter one such "on site" variable has been studied.

9.1 Ideal System

Any system, in a perfect world follows the natural laws of evolution. The rate of growth or decay of the system, tends to have a distribution which follows the biological growth curve. The same could be said to be true on the building site. If the assumption is made that the building site is perfectly organised and perfectly adaptable to the external influences, then it follows that the activity rate, day by day, will follow the biological growth curve. The mathematical logic of the above argument is developed in the following manner.

Take that on a ideal building project there are altogether 'N' units of work to be done, and at a particular point of time 't', n units have already been completed, then (N-n) remain to be done. Assume that the rate at which work is possible on the

remaining units depends upon the amount to be done, then

$$\delta n \sim \lambda n . \delta t \qquad (9.1)$$

and the pressure to finish the projects depends upon the amount of work still left (N-n)

or $$\delta n \sim \mu (N-n) \delta t \qquad (9.2)$$

where λ and μ are two constants.

From the equations (9.1) and (9.2)

$$\frac{dn}{dt} = K (N-n)n \qquad (9.3)$$

where K is another constant.

In the argument given above it has been assumed that during the construction process the external influences remain unaltered.

From equation (9.3) we get

$$\frac{dn}{n(N-n)} = K. \, dt$$

$$\text{or} \quad \frac{dn}{n} + \frac{dn}{(N-n)} = NK \, dt$$

Integrating the above equation

$$\log n - \log (N-n) = NKt + C$$

Where 'C' is the constant of integration

$$\log \frac{n}{N-n} = NKt + C \qquad (9.4)$$

Let 2T be the construction time, and the job is planned in such a way that when t = T, the job is half done

$$\text{i.e.} \quad \text{when} \quad t = T, \quad n = \frac{N}{2}$$

With these initial conditions, from equation (9.4)

$$\log 1 = 0 = NKT + C$$

or $$C = -NKT$$

$$\text{constant } C = -NKT$$

or $$\log \frac{n}{N-n} = NK(t - T) \qquad (9.5)$$

Consider the case when $t > T$

then $$\frac{n}{N-n} = e^{NK(t-T)} \qquad (9.6)$$

and when $t < T$

$$\frac{N-n}{n} = e^{NK(T-t)} \qquad (9.7)$$

Let us assume that the labour input is an "on site" variable and the man week is a unit of work. In such a case, if the site is perfectly planned and organised the weekly labour return figures on the site should follow the above mentioned distribution.

9.2 Real System

The conditions mentioned above do not represent the true picture of the construction process on the building sites. The external influences which are beyond the control of the site management are changing all the time. This is reflected in the rate of change of the activity rate on the building site, which in response to changes in the external factors deviates from the expected growth pattern. Because of the unexpected changes in the external factors there are all too frequent occasions when actual progress to date differs from the programme. Whenever

such a situation arises on the building site, the Site Manager has to take decisions, in order to redeploy the available resources in such a way so as to strike a compromise between the programmed and the actual situation, using his experience and intuition as his guide.

It is obvious that whatever method of control is employed on a building site, it must be dynamic in the sense that it should take account of the actual situation rather than the programmed situation, e.g. whenever a group of men is ready to start a fresh piece of work, and there is more than one operation ready to be started, the Site Manager must decide whether to employ a greater labour force or to perform the separate operations in sequence. Conditions may also arise when, due to inclement weather, non-availability of information or non-availability of materials, there is insufficient work for the men on the site. Under such conditions the most appropriate decision that the Site Manager can take may be to transfer a proportion of his labour force to some other site when there is labour shortage. Failure to take the right decision can lengthen the total contract period or it may be reflected in the form of unproductive labour time. It could be said, therefore, that the efficiency of operational control on the building site depends upon the rate at which the resources on that site are re-adjusted to take into account any changes in the external factors. In other words if we can develop

an index which is sensitive to changes in the external influences, then the same index could be used for measuring the operational control on the building sites.

9.3 Index of Operational Control - P_2

The weekly labour returns on the selected building sites were studied and the figure ($\frac{\Sigma dn}{T} \times N$) was chosen as the above mentioned index. It will in future be referred to as P_2.

thus $P_2 = \frac{\Sigma dn}{T} \times N$

where dn = change in the weekly labour force

N = total number of man-weeks involved on the site

T = construction time in weeks

9.4 The labour return figures were obtained for 12 building sites and P_2 values calculated. They are given in Table No.

No.	Project Reference No.	P_2
1	P/11	5.89
2	P/28	5.21
3	P/29	4.52
4	P/36	4.41
5	P/87	3.87
6	P/323	5.94
7	P/339	10.8
8	P/359	7.81
9	P/491	2.14
10	P/516	3.75
11	P/517	6.01
12	P/527	7.44

TABLE NO. 17

9.5 P_1 Vs P_2

Table No. 18 gives the P_1 and P_2 values and also the rank orders of 10 different projects which were considered to be similar. They were all residential buildings. It is assumed here that similar jobs have similar external forces. It is also assumed that changes in local factors effect equally the external factors.

No.	P_1	Rank Order	P_2	Rank Order
1	32	9	5.89	6
2	30	$7\frac{1}{2}$	5.21	5
3	22	3	4.52	4
4	24	4	4.41	3
5	26	5	5.94	7
6	30	$7\frac{1}{2}$	10.8	10
7	34	10	7.81	9
8	8	2	3.75	2
9	28	6	6.01	8
10	6	1	2.14	1

TABLE NO. 18

The Spearman's[1] rank correlation coefficients between P_1 and P_2 values = 0.80.

(1) $r = 1 - \frac{6 \sum d_i^2}{n(n^3 - 1)} = 1 - \frac{6 \times 32.5}{990} = 0.80$

The student's 't'[2] value = 3.77 with 9 degrees of freedom. This is significant at about 0.2% level. This suggests that there is a high association between the two indices P_1 and P_2.

In other words, the sites which are considered to be well organised by the Site Manager also have a relatively high P_2 value. Therefore we can conclude that both P_1 and P_2 are measuring some actual state of affairs on the site. P_2 is a measure of the sensitiveness of site control to changes in the external factors and we shall call it the Index of Operational Control.

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[2] $t = r\sqrt{\frac{(N-2)}{(1-r^2)}} = 3.77$ with 9 degrees of freedom.

CHAPTER 10

BUILDING SITE ACTIVITY - INPUT/OUTPUT CONCEPT

A building, however large, however small, demands for its erection several Inputs. They include physical ones, which are land, drawing details, building materials and craftsmen. Another organisational Input which is equally important is the experience, judgment, wisdom and the skill of the man in charge on the building site. In Chapter 8 we studied the latter Input in great depth and have shown that there is a definite structure in this Input factor. But no "Output" index has yet been developed in the S.E.B.I. Study that is sufficiently consistent for us to employ as correlate with our highly significant indices. Factor analysis of the response matrix described in Chapter 8 has shown it quite clearly that in the view of the Site Managers the three major problems of the building site in order of priority fall under the following factors.

1. S.O. Factor
2. 'A' Factor
3. 'L' Factor

We shall now study these three factors separately in order to find out what in fact these factors consist of.

10.1 S.O. Factor

The items which were included in this factor were, in brief, the following

Item 4 Availability of the Architect for decisions.

Item 8 Speed with which the firms management attended to the Site Supervisor's problems.

Item 18 The availability of drawings and other details at the time required.

Item 27 The availability of materials when needed.

Item 29 The specifying of particular suppliers or products and their availability at the time required.

The five items deal with the interdependence of the site activities with actions or inactions of parties external to the site. The building site cannot be isolated from the work of designers, suppliers, sub-contractors and the firm's own higher management . The Site Manager sees the role of co-ordinating all those engaged in supplying the physical inputs on the site as the key to effective site performance.

The problems of co-ordinating become even more aggravated because of the presence of yet another central characteristic which is a commonly shared experience of all those involved in the construction process i.e. uncertainty. Those who plan and control operations on the building site cannot know beforehand if the resources they must include in their plan will materialise at the time assumed or even accord to the specification. Certain

instances and problems which were actually mentioned by the Site Managers during the field studies are given below.

On one of the sites visited, the Site Agent complained that the drawings provided by the Architect were either incomplete or incorrect. Measurement had to be taken on the site before ordering the window frames and the electrical fittings, and get them confirmed by the Architect. No single architect was appointed for this particular site and considerable time was wasted before he got the confirmation from the designers. The effect of the delay in making the decision was cumulative in the sense that the materials were also ordered later than the anticipated date. The contract was completed two months after the scheduled completion date. It is wrong to assume that this delay was purely due to the lack of capacity of the designer to take a prompt decision, but it is true that considerable effort would have been saved if the architect was available when needed. This is a problem of lack of effective co-ordination between design and construction.

On one of the sites the contractors had received provisional substructure drawings, and some of the superstructure plans. All of the 'system' drawings were available, but some confusion had arisen in relating the appropriate drawings to the Architect's plans. The 'system' drawings contained a lot of redundant information; there were, for example, many more types of window detailed that would be required for this particular job. Due to complexities

of coding, the contractors found it difficult to locate the corresponding details on the 'system' drawings. There was also difficulty in relating the superstructure elevations on the Architect's drawings to the appropriate substructure elevations on the structural engineer's drawings. The Q.S. also provided a bill of quantities which made no reference to this particular site. The central management of the firm also did not help very much to solve this problem. They tried to settle the matter without bringing the Site Manager into the picture. This contract was completed one month after the scheduled completion date.

During the investigation, we came across a site where the contract was finished before the scheduled time in spite of the fact that some of the materials specified by the designer were in acute shortage. This was achieved by maintaining a very close co-ordination between the designer, contractor, quantity surveyor all through the contract. Partitionings were in shortage, they got over it by specifying an alternative material which was available in the market. The Architect was always prepared to co-operate and so were the central management of the firm. During the planning stage of the contract some very concrete suggestions were made by the Site Agent regarding the structural construction which were accepted by the designer and the design was modified accordingly.

One Site Manager complained that although he sent his weekly reports regularly to the department concerned, with such information as man-hours, actual progress as against programmed situation, material usage, he was never informed about his relative performances on the site. There was lack of confidence in the ability of the site management. This was revealed in the interviews with the Contracts Manager. No attention was given to the suggestions made by the Site Manager regarding the possibilities of improving the performance on the site. This was a case where there was no proper feed-back of information which created an atmosphere of mistrust and instability.

10.2 A-Factor

The items included under this heading were in brief the following:-

Item 6 Confidence in workers integrity.

Item 8 Admission that planning etc. demands more than experience.

Belief in his own need for training.

Item 11 Belief that Architect understands problems of site agent.

Item 17 Recognition of need for new thinking in himself.

Item 21 Belief that bonus systems are not bribery.

Factor II, at first sight, appears to be loaded with items that have little relation to each other. Three elements seem to be involved. Firstly, items 6 and 21 suggest the attitude of the Site Agent towards an important aspect of his operatives, namely, whether they are prepared to do a fair day's work for a fair day's pay.

The first suggests how far the Site Agent sees the men as concerned mainly to increase their wages and diminish their hours of work; the second suggests how far he believes that bonus schemes do not so much reward the men for their work as prevent them from leaving the job. Agreement with these propositions indicates an uncharitable or even cynical attitude to the work people.

Items 8 and 17, on the other hand, suggest how far the Site Manager is aware that, in order to handle successfully a complex, modern job he himself needs other than mere experience. They measure, as it were, how far the Site Manager will acknowledge his own need for training and additional qualifications. It is interesting to see that these two sets of ideas are significantly associated. Site Agents who admit their own need for new skills or technical knowledge are significantly less inclined to see their own men as interested only in the amount of their wages, and thus prepared to earn them, than are Site Agents who feel they have little need for other than their past experience.

But it is of great interest to see that the Site Agents who hold these more flexible attitudes are those who acknowledge that their Architects have understanding of the Site Manager's problems. We therefore denote this five item factor by the symbol A. This may be taken to mean either Architect, or Authority, for it has

already been shown both in Factories[1] and Hospitals[2], that subordinate managers are both more ready to admit their need for constant learning and more sympathetic towards the needs of their subordinates when their own superiors are perceived as being concerned to help them with their own problems.

Factor II, then, or our A-Factor, is both more homogeneous and more intelligible if we make this examination of its elements. It is the factor on the building sites that illustrates the general thesis[3] that "in conditions of uncertainty middle managers tend to pass on to their subordinates the attitudes they detect in their superiors".

The Site Manager, in other words, will try to help himself by learning , and also will try to help his work people, by seeing that they may have ambitions other than the desire for higher pay, if, in turn, he sees the Architect as trying to understand the problems of the Site Manager. (We note that this conclusion is significant at 1%; it is therefore undeniable.)

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(1) M. I. Hussain - Ph.D. Thesis, Discriminant Model for the Analysing of Factors Influencing Innovation in Industry. Jan. 1965.

(2) R. W. Revans - Standards of Morale, Cause and Effect in Hospitals. 1964.

(3) R. W. Revans - Theory of Practice in Management. 1966.

10.3 L-Factor

Factor III has been shown to be only significant at 10% level. This factor is loaded into the five items 1, 19, 23, 25 and 32. The low level of significance of this factor is probably due to the lack of discriminatory power of items and thus reflects on the limitations of the questionnaire. However, it is important to study the implications of the items involved in this factor. The items in brief are as follows:-

Item 1 Belief that men do not expect high standards of site accommodation and welfare.

Item 19 Admission of the fact that because of too many uncertain factors too much time and capital can be spent in planning and programming.

Item 23 Belief that casual employment discourages keeness and efficiency.

Item 25 Recognition of the need for more co-operation between site management and operatives.

Item 32 Belief that the builders should keep same men from one job to another.

Two elements seem to be involved. Firstly, the items 1, 23, 25 and 32 suggest the attitude of the Site Managers towards the working conditions on the site and labour turnover. Secondly, the item 19 suggests the attitude towards planning and programming in the conditions of uncertainty inherent in the building industry. The item 19 is not significantly correlated to any of the other four items in Factor III in spite of the fact that this factor is loaded into item 19. This

could be accounted for by the assumption that this factor falls in the fringes between Factor II and Factor III. However, all the other four items included in this factor deal with labour and we therefore denote this factor by the symbol 'L'.

It is of great interest to see that the Site Managers who believe that working conditions on site need to be improved also believe that the knowledge and experience of the operatives should be appreciated by site management. During the field studies we came across several instances where Site Agents relied upon the experience of his operatives with very beneficial results. These Site Agents also believed strongly in the necessity for improving working conditions on building sites in order to keep labour turnover low.

During the field studies high labour turnover was found to be one of the main factors affecting labour costs. For any job which is not just unskilled labouring, this inevitably means a loss of time while the new individuals adjust themselves to the task in hand. On one of the sites visited 4 out of 12 carpenters left in one afternoon. The steps that were taken by the contractors to ensure adequate labour on the site were as follows

(i) To pay more directly to labour in the form of wages, bonuses or special allowances.

(ii) To encourage labour to join the permanent staff with special pensions, sick pay and holiday benefits.

(iii) To retain the labour in the firm in spite of the fact that there was no work available for them. This was

particularly true in cases of skilled labour.

The methods which were suggested by the site managers to overcome this difficulty are summarised below:-

1) The use by contractors of more mechanised equipment.

2) Using more prefabricated components.

3) Improving the working conditions on the building sites and a general improvement in the image of the industry.

4) Using the labour more productively. This means that a scientific study of the labour utilisation on the site should be carried out in order to introduce those conditions which would give higher labour productivity.

5) Better planning methods so that the labour required during the different stages of the contract are forecasted more accurately.

6) More comprehensive training of the operatives to enable a man to carry out more than one trade should the occasion arise. On one of the sites considerable time was saved when, because of serious shortage of tilers, the contractors suggested that the bricklayers lay tiles under the supervision of one or two more experienced tilers. The co-operation from both trades was sought and granted, and expensive delays were avoided.

7) By introducing incentive schemes which are acceptable both to management and the operatives. This could be achieved by explaining the aim and the method of the incentive scheme and removing any mistrust and doubt.

CHAPTER 11

CONCLUSIONS AND RECOMMENDATIONS

After a study of the background of the industry and an examination of the results obtained through this investigation, the following conclusions are drawn and recommendations made.

1. The study has shown that there is a presence of crisis management on the building sites. Although this type of management is a symptom of an organisational malaise it is likely to continue as long as uncertainties endemic in the present system persist. Its cause lies in the general lack of co-ordination either within the firm or due to the fragmentation of the roles of the parties involved in the building process. It is clear that there is no one person able to control or co-ordinate the activities in the entire building process.

2. The study of the building sites has indicated that delays on the sites stemmed predominantly from lack of clarity or non-availability of information. Non-availability of materials at the desired time and plant breakdown etc. were the other causes of delays.

Delays arising from the information flow fall into three groups, viz. those which are due to inadequate information, those which are due to faulty information, and those cases where the information is channeled to the wrong party. The first requires standardised procedures and format so that by the use of check

lists this can be resolved. The second failure could be legislated against, but requires experience and skill on the part of the designers to move towards perfection. However a number of aids could be used, especially with complex structures, which may be represented by a model. Alternatively, the acceptance of the principle that certain aspects of design are best determined at the construction stage. However this acceptance necessitates the integration of design and production, and the involvement of the designer in site management. The third is due to lack of co-ordination between the different parties contributing to the building process. It is suggested that a random sample of typical delays observed on the building sites should be thoroughly investigated and not merely shrugged off as unavoidable.

3. The study has shown that the site managers seem to feel strongly the need for continuous personal involvement during programming and personal control on matters dealing with the designers. Factors which were regarded as most important by the site managers were:

a) Presence during initial preparation of the programme.

b) Negotiation for the interpretation of drawings.

The important aspect involved in the first of the two factors, is the classification of the roles and responsibilities of the persons concerned with the construction, when a 'planner' as such is employed. This involves a policy directive to define

whether planning is a service to the site or a directive to the site. In the latter case the planner must accept the responsibility of events on the site. If the former policy is adopted the plan ought to have the approbation of the site manager and to do this his participation is essential.

It is noteworthy that 30 of 68 site managers who provided the information had no part in the preparation of the programme, and only 19 reported full participation. Those who were not involved in the preparation of the programme felt frustrated, as they could not contribute their own knowledge and experience. It was found that 80% of the site managers who took part in the attitude analysis believed they could have beneficially influenced overall performance had they been consulted.

Some of the site managers were suspicious of the utility of detailed formal planning techniques; these suspicions could have arisen from fear and ignorance of formal planning techniques as much as from uncertain conditions existing in the building process; to overcome this they felt the need for secure and formalised backing from the firm. This could be achieved by actively and continuously engaging the site manager in the planning of the construction programme, as this would not only give them a good background into the problems involved in the construction but also help them in learning new methods of planning and control.

The second factor is necessary because often during the course of the construction work when the interlocking effects of decision and drawings etc. produces a situation of incompatability, they have to be resolved speedily if progress is not to be interrupted.

The authority to deal with the union on matters relating to labour disputes and welfare is regarded as the least important by the site managers. This may be due to the fact that they are conditioned by the general practice of the higher management to retain control of this aspect.

4. The study of the authority delegated to the site manager as against what he actually assumed shows that there is conflict existing between the central management's statement of the area of control of site managers and the degree of direct control exercised by the site manager. The conflict is studied by examining the extent of agreement and disagreement between these aspects.

The Table No. 19 gives the distribution of projects where disagreement was observed. Three aspects (a, b, c - reference Chapter 5) of control were studied. This table is obtained from Appendix Tables 3a and 3b.

Aspect of control	No. Projects		
	Control exercised by Site Manager in excess of authorised	Control exercised by Site Manager less than authorised	Where differences are marginal
a	3	21	30
b	0	24	30
c	4	19	31

TABLE NO. 19

It would appear from Table No. 19 that on a considerable number of sites which were included in this study, the extent of authority delegated to the site management was not fully exercised.

This could be due to two reasons

1) Although the central management delegated authority to the site they resent it if it is assumed by the site

2) Problems where clarification of information is needed, may lead to a deterioration in the firms relations with the designer where the site manager effects a decision on his own initiative, without prior consultation with the central management; the detrimental effect of this may also trace itself back to the site manager. This is most likely to arise where a solution may involve financial considerations which may subsequently have to be subject of monetary claim with a possibility of apportioning the blame for lack of foresight.

It is suggested that the definitions of the roles and responsibilities of the site manager needs setting out in very clear terms after a study has been made to ascertain whether productivity can be affected by location of control.

5. The study has shown that the factor most affecting the performance on the building site arises out of the interdependence[1] of the parties contributing towards the construction process and their inability to take action promptly and effectively. This is caused by their lack of understanding of the problems on the site. It is therefore suggested that those involved in the construction should form a interdisciplinary research team. This would enable them to perceive the problems more clearly and arrive at an agreed conclusion.

It is suggested that junior members of the professions and junior management and experienced site managers should be given the opportunity to study the problems together, in collaboration with disciplines available in academic institutions. The most practical move towards the co-operation between industry and the universities would be the invitation from industry to the universities and the colleges to join in the study, both long term and short term, of real management problems in the setting where they exist. Such a study should have a two way feed-back.

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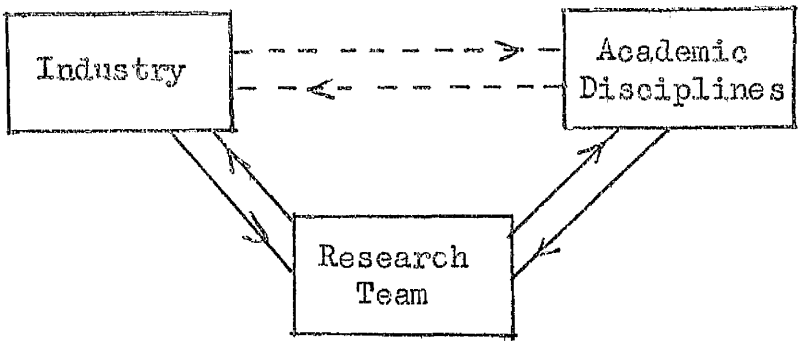
(1) Similar conclusions have been drawn by Tavistock Institute of Human Relations in their report "Communication in the Building Industry" Realisation Report. (available only to limited circulation)



The following advantages would flow from a well-organised research project of this kind

1) The personal involvement to some degree of potential management, and this will provide them with a learning opportunity.

2) This will give them an opportunity for a realistic examination, appraisal and treatment of the operational problems encountered, during the course of the research.

3) In consequence, this will create a desire among the senior management of the parties represented in the team for further self-development, out of which proposals for continued study would originate and would be made more specific in the course of discussions with the members of the academic staff.

4) Group collaboration of this kind will lead to a better understanding not only of techniques involved in the building process, but of the roles and responsibilities of the parties involved.

5) The opportunities they would get during the investigation of collecting, recording and interpreting information would give them a better understanding of the information flow in the building process and thus a chance to improve upon it.

A study of this kind needs the active support of all the parties involved in the building process.

During the course of the investigation it was found that progress on certain sites was delayed by shortage of materials. The situation was made worse by the increase in the number of orders placed by the users, because of rumours that certain materials were in short supply. This problem could be tackled effectively by forecasting the demands for building materials and studying the stability[1] of the supply and demand system. This is a case where research undertaken jointly by suppliers, contractors, designers and universities along the lines suggested by G. Bayley[2] would be of great help to the industry.

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(1) Industrial Dynamics - J. W. Forrester

(2) Work Load and the use of Materials, Builder 14th May 1965. - Gordon Bayley

APPENDICES

APPENDIX 1.a

Site

Is the site agent/foreman delegated authority to:

a. Call for delivery of materials: [Direct] [Through H.Q.]

b. To negotiate the interpretation of drawings: [Direct to Architect] [Through Others]

c. To call for type of plant: [Direct from Depot] [Direct from Plant Firm] [Through H.Q.]

d. Is his authority to recruit men on site: [Absolute] [Limited] [Nil]

e. Is his authority to discharge men from site: [Absolute] [Limited] [Nil]

f. Is his authority to negotiate with the unions on:

   a. Bonus rate - [Absolute] [Limited] [Nil]

   b. Welfare conditions - [Absolute] [Limited] [Nil]

   c. Disputes - [Absolute] [Limited] [Nil]

g. Between the award of the contract and the start of the work on site, did the site agent/foreman take part in preparing the initial programme (in time) 100% 80% 60% 40% 20% 0%

h. Has he authority to negotiate with sub-contractors on: [All matters incl. finance] [All matters excl. finance] [Limited] [None]

i. No. of apprentices on site: .....

j. Safety Officer responsible for this site has overall responsibility for ..... sites.

APPENDIX 1.b

1.	Did you call forward materials			
	a. direct from supplier	Frequently	Seldom	Never
	b. through H.Q.	"	"	"
2.	Did you recruit men			
	a. on site	"	"	"
	b. through H.Q.	"	"	"
3.	Did you negotiate on drawings			
	a. direct with Architect	"	"	"
	b. through H.Q.	"	"	"
4.	Did you call for plant			
	a. direct from H.Q.	"	"	"
	b. direct from Plant Hire firm	"	"	"
5.	Did you negotiate direct with unions			
	a. on bonus rates	"	"	"
	b. welfare conditions	"	"	"
	c. dispute	"	"	"
	or did you request H.Q. to deal with unions	"	"	"
6.	Did you negotiate with sub-contractor (except financial matters)			
	a. direct	"	"	"
	b. through H.Q.	"	"	"
7.	Did you <u>participate</u> in planning of the works		Yes / No	
	or were you only consulted		Yes / No	
8.	Did you receive a programme of the works			
	a. before start on site		Yes / No	
	b. after start		Yes / No	

APPENDIX 2

1 Building as an out of door activity is such that the men do not expect high standards of site acommodation and welfare.

SA A UD DA SDA
8

2 The task of the supervisor of a building contract today calls for experience, judgment and training of high order.

SA A UD DA SDA
8

3 An Agent or General Foreman who has had plenty of practical building experience would gain very little help in his work from training courses in site management.

SA A UD DA SDA
8

4 One of the noticeable features of this present job is the ready availability of the architect for decisions.

SA A UD DA SDA
8

5 In our firm management attends to the site supervisor's problems so promptly that he has no cause for complaint.

SA A UD DA SDA
8

6 If you paid the operatives more than at present they would simply work shorter hours.

SA A UD DA SDA
8

7 Contractors should handle all disputes at top managerial level.

SA A UD DA SDA
8

8 A Site Manager trained in traditional building practices would find no difficulty with the programming and control procedures at this site.

SA A UD DA SDA
8

9 If a minute to minute study were made of how most Agents spend their time on site, we should discover that a great deal too much of that time was given to chasing and interpreting the designers instructions, drawings, specifications etc.

SA A UD DA SDA
8

10 On this particular job the output could have been considerably increased if the Site Agent was brought in at the initial programming and planning stage.

SA A UD DA SDA
8

11 Whatever Site Agents may not know about the work of Architects it is clear that many Architects know very little about the problems of Site Agents.

SA A UD DA SDA
8

12 Proper warning of requirements was given to the suppliers of materials to this site but a significant number failed to meet delivery dates.

SA A UD DA SDA
8

13 The important thing about a delay on a building job is not that it may postpone the occupation of the building, but that the causes for the delays should be clearly identified.

SA A UD DA SDA
8

14 The job of planning and programming any building work should be left to the experts in the Head Office.

SA A UD DA SDA
8

15 Disputes on a building site are best settled by independent third parties who do not need to live with whatever solution is agreed.

SA A UD DA SDA
8

16 Any average man with site experience can organise building work providing he is given the time.

SA A UD DA SDA
8

17 The problems of scheduling and control arising on this particular job are such that practical experience of traditional methods, however extensive would be of themselves insufficient qualifications.

SA	A	UD	DA	SDA
8				

18 It is rare for work to be held up on the job through lack of drawings or information.

SA	A	UD	DA	SDA
				8

19 Because of too many uncertain factors in the Building Industry, too much time and capital can be spent in planning and programming.

SA	A	UD	DA	SDA
				8

20 Regular meetings between Operatives representatives and the site supervision would be a waste of time.

SA	A	UD	DA	SDA
				8

21 Bonus systems are a disguised form of bribery to make recruitment possible without infringing the basic wage agreements.

SA	A	UD	DA	SDA
				8

22 Higher standards of site accommadation and welfare are essential to encourage men to meet current demands upon the industry.

SA	A	UD	DA	SDA
8				

23 Taking on men for the duration of a job only discourages keenness and efficiency.

SA	A	UD	DA	SDA
8				

24. Modern building requires modern techniques and continuous training for site managers during their career.

SA	A	UD	DA	SDA
8				

25 Unless the operatives feel that site management is concerned and is anxious to have the benefit of their views for improving productivity, then progress will be unfavourably affected.

SA 8 | A | UD | DA | SDA

26 Workers in the Building Industry are paid far too much for the amount of responsibility they have.

SA | A | UD | DA | SDA 8

27 Significantly more progress could have been made on this particular job if materials had been available when needed.

SA | A | UD | DA | SDA 8

28 The bonus scheme on this site really rewards men for their individual effort.

SA 8 | A | UD | DA | SDA

29 The designer of this building clearly did not enquire if the materials he specified could be obtained in time to complete the contract within the period allowed.

SA | A | UD | DA | SDA 8

30 "Every responsible manager must from time to time refer problems to his superiors". The majority of Site Agents or General Foremen today do this but seldom get a prompt decision.

SA | A | UD | DA | SDA 8

31 There have been few occasions during the course of this particular job when Industrial unrest could not have been handled with complete success by those on site.

SA 8 | A | UD | DA | SDA

32 The best builders are invariably those who keep the same men from one job to another.

SA 8 | A | UD | DA | SDA

33 To make the most of the limited resources available to the industry too much emphasis cannot be placed on planning and programming.

SA | A | UD | DA | SDA 8

APPENDIX No. 3

In this Appendix* an attempt has been made to explain certain principles involved in the analysis of the correlation matrix in Chapter 8.

In the Matrix No. 3 in Appendix one is concerned with the set of n individuals each of which bears the value 'p' different variates. The multivariates characteristics lie in the multiplicity of the variates not in the size of the set .

The 'p' variates are dependent among themselves so that one cannot split off one or more from the others and consider it by itself. In this particular case the responses vary considerably between each individual for the different items, and yet possibly, there are certain vague similarities which run through groups of individuals, or groups of items, not very well marked off from one another, but merging into neighbouring groups at their margins. There is a tendency for the variates to fall into groups. In the analysis an attempt has been made to recognise these groups (if they exist) and if possible to extract them.

A3.1 Suppose there are 'p' variates $y_1, y_2 \cdots y_p$, each observed on individuals. Let y_{ij} represent j^{th} observation on the i^{th} variate, so that the observations may be arrayed in a Matrix.

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* M. G. Kendall - A course on multivariate analysis.

$$\begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \vdots & \vdots & & \vdots \\ y_{n1} & y_{n2} & \cdots & y_{pn} \end{bmatrix} \quad \text{-------(1)}$$

The object of the analysis is to economize in the number of variates. To do this one has to seek for linear transformations of the type

$$z_i = \sum_{j=1} a_{ij} y_j \text{ , where } i = 1, 2, \ldots p \qquad (2)$$

In practice, when the variation is obviously non-linear it is best to try to transform to linear variation before embarking on an analysis

It may be possible that the data could be expressed in terms of fewer number of variates of z's. In such a case a genuine reduction in the complexity of the problem has been achieved. But this is exceptional. Where such a reduction is not possible, the dimension of the problem could be reduced by choosing the coefficients so that the first of the new variates z_1 has as large a variance as possible. The second new variate z_2 could be so chosen that it is uncorrelated with the first and it has as large a variance as possible. In this way, one can transform to new uncorrelated variates which account for as much of the variation as possible in descending order. In such a case, it is possible to say that first few variates are responsible for

the largest variation and the rest could be neglected.

Let us take each y_i measured about its mean, so that

$$\sum_{j=1}^{n} y_{ij} = 0 \quad , \quad i = 1, 2 \ldots\ldots p, \cdots (3)$$

also let us standardise so that $y's$ have unit variance. Then

$$\frac{1}{n} \sum_{j=1}^{n} y_{ij}^2 = 1, \quad i = 1, 2, \ldots . p. \text{ ---- } (4)$$

the the $(p \times p)$ matrix whose i^{th}, j^{th} term is

$$Cov\,(y_i, y_j) = \frac{1}{n} \sum_{k=1}^{n} y_{ik} \cdot y_{jk}$$

is a factor in n times the product of (y_{ij}) and its transpose. Except for a factor n this is the <u>correlation matrix</u>, which could be written as

$$\begin{bmatrix} 1 & r_{12} \ldots\ldots & r_{1p} \\ r_{21} & 1 \ldots\ldots & r_{2p} \\ r_{31} & r_{32} \ldots\ldots & r_{3p} \\ \\ r_{p1} & r_{p2} \ldots\ldots & 1 \end{bmatrix} \quad \ldots\ldots (5)$$

All the diagonals of such a Matrix would be 1.

Principal Components

Consider the n points in the space of 'p' dimensions when the y's are expressed in standard measure. Consider the line in such a space with current co-ordinates Y

$$\frac{Y_1 - m_1}{l_1} = \frac{Y_2 - m_2}{l_2} = \cdots\cdots\cdots = \frac{Y_p - m_p}{l_p} \quad \ldots\ldots (6)$$

Where l's are direction cosines and are therefore subject to the conditions

$$\sum_{i=1}^{p} l_i^2 = 1 \quad \cdots\cdots\cdots \quad (7)$$

The sum of squares of the distances from the n points to this n S line is given by

$$n S = \sum_{j=1}^{n} \left[\sum_{i=1}^{p} (y_{ij} - m_i)^2 - \left\{ \sum_{i=1}^{p} l_i (y_{ij} - m_i) \right\}^2 \right] \ldots\ldots (8)$$

If this is a stationary value the partial differentials with respect to m's vanish and hence

$$- \sum_{j=1}^{n} (y_{ij} - m_i) + \sum_{j=1}^{n} l_i \sum_{i=1}^{p} l_i (y_{ij} - m_i) = 0 \ldots\ldots (9)$$

where $i = 1, 2, 3 \cdots \cdots \cdots p$

Since $\sum_j y_{ij} = 0$ this leads to

$$\frac{m_i}{\ell_i} = \text{constant}$$

Hence, the origin lies on the line (6) and without loss of generality one can take all the $m_i' \leq 0$, then since,

$$\sum_{j=1}^{n} y_{ij}^2 = n \quad , \qquad \text{we have}$$

$$n S = \sum_{j=1}^{n} \left[\sum_{i=1}^{p} y_{ij}^2 - \left(\sum_{i=1}^{p} \ell_i y_{ij} \right)^2 \right] \cdots \text{from Equation (8)}$$

$$= np - \sum_{j=1}^{n} \left(\sum_{i=1}^{p} \ell_i y_{ij} \right)^2 \cdots\cdots\cdots (10)$$

We then find the stationary values of S for variations in ℓ subject to 7. If λ is an undetermined multiplier this leads to

$$-\frac{1}{n} \sum_{j=1}^{n} y_{kj} \left(\sum_i \ell_i y_{ij} \right) + \lambda \ell_k = 0, \; k = 1, 2, \cdots p$$

$$\cdots\cdots\cdots (11)$$

or the set of 'p' equation given by

$$\left.\begin{aligned}
&\ell_1 (1-\lambda) + \ell_2 r_{12} + \cdots\cdots\cdots + \ell_p r_{1p} = 0 \\
&\ell_1 r_{21} + \ell_2 (1-\lambda) + \cdots\cdots + \ell_p r_{2p} = 0 \\
&\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
&\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
&\ell_1 r_{p1} + \ell_2 r_{p2} + \cdots\cdots + \ell_p (1-\lambda) = 0
\end{aligned}\right\} \cdots (12)$$

if the ℓ's are eliminated the equation no. 12 could be written in the Matrix form as

$$|r - \lambda I| = 0 \quad \text{----------(13)}$$

which represents the characteristics equation of the correlation matrix. When r is known this equation (13) gives p roots of λ. corresponding to each root of λ there is a ℓ' for which S has a stationary value. Moreover from (11) and (10).

$$S = p - \lambda \quad \text{---------} \quad (14)$$

which shows that λ cannot have negative values.
Furthermore, it follows from equation (14) that the root which gives the minimum S is the one with the largest λ. Choosing the largest root of (13) therefore gives us the line required. The sum of squares of distance of the points from it is a minimum and the variate measured along it has the maximum variance. The new variates are given by

$$z_1 = \sum_{j=1}^{p} \ell_{1j} y_j \quad \text{-------(15)}$$

Where ℓ_{1j} with the subscript j represents the sets of ℓ's related to the root λ_1

Variance of z_1 is equal to λ_1

let $l_{\alpha i}, l_{\beta i}$ are the l's corresponding to any two different roots λ_α and λ_β then l's are orthogonal, that is to say

$$\sum_{i=1}^{p} l_{\alpha i} \cdot l_{\beta i} = 0 \,, \quad \text{if } \alpha \neq \beta \text{ ------ (16)}$$

Now from equation (12)

$$\sum_{j=1}^{n} l_{\alpha j} \cdot r_{ij} = \lambda_\alpha l_{\alpha i}$$

and $$\sum_{j=1}^{n} l_{\beta j} \cdot r_{ij} = \lambda_\beta \cdot l_{\beta i}$$

multiply the first by $l_{\beta i}$ and the second by $l_{\alpha i}$, and subtract, then

$$\sum_j \left(l_{\alpha j} \cdot r_{ij} \cdot l_{\beta i} - l_{\beta j} \cdot r_{ij} \cdot l_{\alpha i} \right) = \lambda_\alpha \cdot l_{\alpha i} \cdot l_{\beta i} - \lambda_\beta \cdot l_{\beta i} \cdot l_{\alpha i}$$

$$= l_{\alpha i} \cdot l_{\beta i} \left(\lambda_\alpha - \lambda_\beta \right) \text{ -- (17)}$$

Summing over i the equation 17.

$$\sum_i^p \sum_j^n \left(l_{\alpha j} \cdot l_{\beta i} \cdot r_{ij} - l_{\beta j} \cdot l_{\alpha i} \cdot r_{ij} \right) = (\lambda_\alpha - \lambda_\beta) \sum_i^p l_{\alpha i} \cdot l_{\beta i} \text{ --- (18)}$$

Now since $r_{ij} = r_{ji}$ the left-hand side of equation no. 18 vanishes and hence

$$(\lambda_\alpha - \lambda_\beta) \sum_i^p l_{\alpha i} \cdot l_{\beta i} = 0$$

hence $$\sum_{i=1}^{p} l_{\alpha i} \cdot l_{\beta i} = 0$$

unless $$\lambda_\alpha = \lambda_\beta$$

That shows $l's$ are orthogonal

Thus if $z_{y_1}, z_{y_2} \cdots z_{y_p}$ correspond to the roots $\lambda_1, \lambda_2 \cdots \lambda_p$ the lines form an orthogonal set. In geometrical terms one could say that the axes of co-ordinates have been changed from y set to z_y set.

As

$$z_{y_i} = \sum_j l_{ij} y_j$$

Then y_i is given by

$$y_i = \sum l_{ji} z_{y_j} \text{ -------- (19)}$$

also

$$\begin{aligned} Cov(z_{y_i}, z_{y_j}) &= Cov\left(\sum_k l_{ik} y_k, \sum_m l_{jm} y_m\right) \\ &= \sum_{k,m} l_{ik} \cdot l_{jm} \cdot r_{km} \\ &= \lambda_i \sum_m l_{im} l_{jm} \\ &= 0 \quad \text{unless } i = j \end{aligned}$$

<u>hence the variates z_y are statistically uncorrelated</u>

Thus the original 'p' variates have now been transformed into a new set of variates z_y which are <u>uncorrelated</u> and have variances $\lambda_1, \lambda_2 \cdots \lambda_p$ in decreasing order, also

If it is assumed that the variates are normally distributed then $z_y's$ may be regarded as constituted of independent components of variances $\lambda_1, \lambda_2 \cdots \lambda_p$ from the total

APPENDIX NUMBER 4

```
COMPILER AB
UED/L4


upper case delimiters
BEGIN
INTEGER m,n
ROUTINE SPEC corrmax (INTEGER m,n)

select input(1)
read(m,n)
corrmax(m,n)

        ROUTINE corrmax (INTEGER m,n)
        ARRAY f,corr(1:n,1:n),w(1:2,1:n)
        INTEGER i,j,f',f''
        REAL s
        ROUTINE SPEC mscabldev (ARRAY NAME c, INTEGER m,n)
        ROUTINE SPEC householder (ARRAY NAME a,w,z, INTEGER n,k)
        ROUTINE SPEC varimax' (ARRAY NAME x,w, INTEGER m,n)
        ROUTINE SPEC ptm''' (ARRAY NAME x, INTEGER m,n,a,b)

        mscabldev (corr,m,n)

        householder (corr,w,f,n,1)
        s=0; f'=0; f''=0
        CYCLE i=1,1,n
        ->18 UNLESS w(1,i)<0.9
        ->19 UNLESS w(1,i)<0.1
        ->17
    18:f'=f'+1; f''=f''+1
        ->16
    19:f'=f'+1
    16:s=s+w(1,i)
        CYCLE j=1,1,n
        f(j,i)=corr(i,j)sqrt(w(1,i))
        REPEAT
        REPEAT
    17:s=100/s
        CYCLE i=1,1,f'
        w(2,i)=w(1,i)s
        REPEAT

        newlines(2); spaces(10)
        CAPTION principal§components
        ptm''' (f,n,f',1,3)
```

```
newlines(2); spaces(10)
CAPTION row␣one␣=␣latent␣roots␣:␣row␣two␣=␣percentage␣variance
ptm''' (w,2,f',2,3)

varimax'( f,w,n,f'')
```

```
ROUTINE mscabldev (ARRAY NAME c,INTEGER m,n)
INTEGER a',b',c',i,j
REAL r,m',m''
ARRAY x,me(1:n)

a'=adr(x(1))
b'=addr(c(1,1))
c'=addr(me(1))
n=n-1; m=m-1

101,13,-,αn
101,27,-,αm

121,21,13,0
121,22,13,0
121,25,13,0

101,11,-,αa'
101,12,-,αb'
101,14,-,αc'

121,30,12,0

346,11,21,0
1:356,30,22,0
203,127,22,1:
124,30,13,1
121,22,13,0
356,14,21,0
203,127,21,1:
```

```
2:121,23,0,0
121,30,12,0

CYCLE i=1,1,n+1
read(x(i))
REPEAT

3:121,21,13,0
122,21,23,0
121,20,21,0

324,11,25,0
300,14,25,0
356,14,25,0

4:324,11,23,0
121,29,23,0
124,29,20,0
342,11,29,0
300,30,20,0
356,30,20,0
203,127,20,4:
124,23,0,1
124,30,13,2
203,127,25,3:
121,25,13,0
203,127,27,2:

121,25,13,0
5:324,14,25,0
1760,0,0,0
356,11,25,0
203,127,25,5:

101,27,-,αm
124,27,0,1
113,27,-,αm

121,30,12,0
121,22,13,0
121,23,11,0

6:324,0,-,αm
```

```
342,0,30,0
301,0,23,0
1711,0,0,0
1715,0,0,0
356,0,30,0
124,30,13,2
124,23,0,1
203,127,22,6:


n=n+1
CYCLE i=1,1,n-1
CYCLE j=i+1,1,n
r=c(i,j)m-me(i)me(j)
c(i,j)=c(i,i)c(j,j)r
c(j,i)=c(i,j)
REPEAT
REPEAT

m'=1/m; m''=1/sqrt(m*(m-1))
CYCLE i=1,1,n
me(i)=me(i)m'
c(i,i)=m''/c(i,i)
REPEAT

newlines(6); spaces(5)
121,23,0,2
10:CAPTION variable; spaces(7)
CAPTION mean; spaces(9)
CAPTION sd; spaces(4)
203,127,23,10:

j=1
17:newline; spaces(9)
i=0
16:print(j,3,0); spaces(3)
print(me(j),3,3); spaces(3)
print(c(j,j),3,3)
c(j,j)=1
i=i+1; j=j+1
```

```
->15 IF j=n+1
->17 IF i=3
spaces(8)
->16
15:newlines(2); spaces(10)
CAPTION correlationsmatrix
ptm'''(c,n,n,1,3)

END



ROUTINE householder (ARRAY NAME a,w,z,INTEGER n,k)
ROUTINE SPEC householder tridiagonalisation( ARRAY NAME a,b,c,INTEGER n)
ROUTINE SPEC tridibisection (ARRAY NAME c,b,w,INTEGER n,REAL NAME norm)
ROUTINE SPEC tridiinverse iteration (ARRAY NAMEc,b,w,z,INTEGERn,REALnorm)
ROUTINE SPEC backtransformation (ARRAY NAME a,b,z, INTEGER n)
ARRAY b,c(1:n)
INTEGERi,j
REAL norm

->2 UNLESS n=1
w(1,1)=a(1,1);a(1,1)=1; RETURN
2:householder tridiagonalisation (a,b,c,n)
tridibisection(c,b,w,n,norm)
RETURN IF k=2
tridiinverse iteration (c,b,w,z,n,norm)
->1 IF n=2
backtransformation(a,b,z,n)
1:CYCLE i=1,1,n
CYCLE j=1,1,n
a(i,j)=z(i,j)
REPEAT
REPEAT
RETURN

ROUTINE householder tridiagonalisation (ARRAY NAME a,b,c,INTEGER n)
```

```
INTEGER i,j,k
REAL ai,sigma,h,bj,bigk,bi
ARRAY q(1:n-1)
->4 IF n=2
CYCLE i=n,-1,3
sigma=0
CYCLE k=1,1,i-1
sigma=sigma+a(i,k)*2
REPEAT
ai=a(i,i-1)
->1 IF ai>0
bi=sqrt(sigma)
->2
1:bi=-sqrt(sigma)
2:b(i-1)=bi
->3 IF bi=0
h=sigma-ai*bi
a(i,i-1)=ai-bi
CYCLE j=i-1,-1,1
bj=0
CYCLE k=i-1,-1,j
bj=bj+a(k,j)a(i,k)
REPEAT
->10 IF j=1
CYCLE k=j-1,-1,1
bj=bj+a(j,k)a(i,k)
REPEAT
10:q(j)=bj/h
REPEAT
bigk=0
CYCLE j=i-1,-1,1
bigk=bigk+a(i,j)q(j)
REPEAT
bigk=bigk/(2h)
CYCLE j=i-1,-1,1
q(j)=q(j)-bigk*a(i,j)
REPEAT
CYCLE j=i-1,-1,1
CYCLE k=j,-1,1
a(j,k)=a(j,k)-a(i,j)q(k)-a(i,k)q(j)
REPEAT
REPEAT
```

```
3:REPEAT
4:CYCLE i=n,-1,1
c(i)=a(i,i)
REPEAT
b(1)=a(2,1)
b(n)=0
END



ROUTINE tridiinverse iteration (ARRAY NAME c,b,w,z,INTEGER n,REAL norm)
INTEGER i,j
REAL bi,bi',z',lambda,u,s,v,h,eps,eta
ARRAY m,p,q,r,int(1:n),x(1:n+2)
lambda=norm; eps=norm*1α-11
CYCLE j=1,1,n
lambda=lambda-eps
lambda=w(1,j) IF w\\(1,j)<lambda
u=c(1)-lambda
v=b(1)
v=eps IF v=0
CYCLE i=1,1,n-1
bi=b(i)
bi=eps IF bi=0
bi'=b(i+1)
bi'=eps IF bi'=0
->1 IF |u|>|bi|
m(i+1)=u/bi
m(i+1)=1 IF m(i+1)=0 AND bi≤eps
p(i)=bi
q(i)=c(i+1)-lambda
r(i)=bi'
u=v-m(i+1)q(i)
v=-m(i+1)r(i)
int(i+1)=1
->2
1:m(i+1)=bi/u
p(i)=u;q(i)=v;r(i)=0
u=c(i+1)-lambda-m(i+1)v
v=bi'; int(i+1)=-1
2:REPEAT
p(n)=u;q(n)=0;r(n)=0
x(n+1)=0;x(n+2)=0;h=0;eta=1/n
```

```
CYCLE i=n,-1,1
u=eta-q(i)x(i+1)-r(i)x(i+2)
->3 IF p(i)≠0
x(i)=u/eps
->4
3:x(i)=u/p(i)
4:h=h+|x(i)|
REPEAT
h=1/h
CYCLE i=1,1,n
x(i)=x(i)h
REPEAT
CYCLE i=2,1,n
->5 IF int(i)≤0
u=x(i-1)
x(i-1)=x(i)
x(i)=u-m(i)x(i-1)
->6
5:x(i)=x(i)-m(i)x(i-1)
6:REPEAT
h=0
CYCLE i=n,-1,1
u=x(i)-q(i)x(i+1)-r(i)x(i+2)
->7 IF p(i)≠0
x(i)=u/eps
->8
7:x(i)=u/p(i)
8:h=h+x(i)↑2
REPEAT
h=1/sqrt(h)
CYCLE i=1,1,n
z(j,i)=x(i)h
REPEAT
REPEAT

END

ROUTINE tridibisection (ARRAY NAME c,b,w,INTEGER n,REAL NAME norm)
ROUTINE SPEC sturms sequence
REAL l,g,h,lambda,p',q',y
```

```
INTEGER i,j,k,a',a''
ARRAY p(1:n)
norm=|c(1)|+|b(1)|
CYCLE i=2,1,n
l=|b(i-1)|+|c(i)|+|b(i)|
norm=l IF l>norm
REPEAT
CYCLE i=1,1,n-1
->1 IF b(i)=0
p(i+1)=b(i)↑2
->2
1:p(i+1)=(norm↑2)*1α-23
2:REPEAT
CYCLE k=1,1,n
g=norm; h=-norm
CYCLE j=1,1,39
lambda=0.5(g+h)
sturms sequence
->3 IF a'≥k
g=lambda
->4
3:h=lambda
4:REPEAT
w(1,k)=0.5(g+h)
REPEAT
RETURN

ROUTINE sturms sequence
p'=0;q'=1;a'=0
CYCLE i=1,1,n
y=(c(i)-lambda)q'-p(i)p'
p'=q';q'=y
a'=a'+1 IF (p'≥0 AND q'≥0) OR (p'<0 AND q'<0)
REPEAT
a'=a'-1 IF q'=0 AND p'>0
END
END

ROUTINE backtransformation(ARRAY NAME a,b,z,INTEGER n)
```

```
INTEGER i,j,k
REAL s

CYCLE j=1,1,n
CYCLE k=3,1,n
->1 IF b(k-1)=0
s=0
CYCLE i=1,1,k-1
s=s+a(k,i)z(j,i)
REPEAT
s=s/(b(k-1)a(k,k-1))
CYCLE i=1,1,k-1
z(j,i)=z(j,i)+s*a(k,i)
REPEAT
1:REPEAT
REPEAT
END
END



ROUTINE varimax' ( ARRAY NAME x,w, INTEGER m,n)
REAL a,b,c,d,e,f,g,h,x',y,z
INTEGER i,j,k,bb,cc,dd

CYCLE j=1,1,m
w(1,j)=0
REPEAT

CYCLE i=1,1,m
CYCLE j=1,1,n
w(1,i)=w(1,i)+x(i,j)*2
REPEAT
w(1,i)=sqrt(w(1,i))
CYCLE j=1,1,n
x(i,j)=x(i,j)/w(1,i)
REPEAT
REPEAT
newline

bb=0; dd=0
10:cc=0
j=1
7:k=j+1
5:c=0
d=0; e=0; f=0; i=1
```

```
2:a=x(i,j)↑2-x(i,k)↑2
b=2x(i,j)x(i,k)
c=c+a; d=d+b; e=e+a↑2-b↑2
f=f+a*b
->1 IF i=m
i=i+1
->2
1:f=2f
g=e-(c↑2-d↑2)/m
h=f-2c*d/m
y=arctan(g,h)
y=0.25y
->3 IF y≥0.01745 OR y≤-0.01745
cc=cc+1
8:->4 IF k=n
k=k+1
->5
4:->6 IF j=n-1
j=j+1
->7
3:a=cos(y)
b=sin(y)
CYCLE i=1,1,m
w(2,i)=x(i,j)cos(y)+x(i,k)sin(y)
x(i,k)=x(i,j)*(-sin(y))+x(i,k)cos(y)
x(i,j)=w(2,i)
REPEAT
bb=bb+1
->8
6:dd=dd+1
->9 IF cc=n*(n-1)/2
->10
9:newlines(2); spaces(10)
CAPTION rotated∅factors
newlines(2); spaces(10)
CAPTION cycles∅∅∅∅rotations
newline; spaces(13)
print(dd,3,0); spaces(8)
print(bb,4,0)
```

```
CYCLE i=1,1,m
x'=0
CYCLE j=1,1,n
x(i,j)=x(i,j)w(1,i)
x'=x'+x(i,j)↑2
REPEAT
x(i,n+1)=x'
REPEAT
newlines(2); spaces(10)
CAPTION last␣column␣=␣sum␣of␣sqs
ptm'''(x,m,n+1,1,3)
z=0; a=100/m
CYCLE j=1,1,n
x'=0
CYCLE i=1,1,m
x'=x'+x(i,j)↑2
REPEAT
w(1,j)=x'; w(2,j)=a*x'
z=z+w(2,j)
REPEAT
newlines(2); spaces(10)
CAPTION row␣one␣=␣latent␣roots␣:␣row␣two␣=␣percentage␣variance
ptm'''(w,2,n,2,3)
newlines(2); spaces(10)
CAPTION percent␣variance␣in␣significant␣factors␣:␣␣␣
print(z,2,1)

END



ROUTINE  ptm''' (ARRAY NAME x, INTEGER m,n,a,b)
INTEGER i,j,k,u,v,w

w=intpt(0.083333n)
->6 UNLESS w=0
u=1; v=n; w=1; k=1
```

```
->10
6:CYCLE k=1,1,w
u=12k-11; v=12k
10:newlines(3); spaces(4)
CYCLE i=1,1,m
print(i,2,0); spaces(3)
CYCLE j=u,1,v
print(x(i,j),a,b); spaces(7-a-b)
REPEAT
newline; spaces(4)
REPEAT
->7 IF k≠w
->8 IF n-v≠0
->9
8:u=v+1; v=n
->10
7:REPEAT

9:END


        END

END OF PROGRAM

***Z
```

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9.	An enquiry into the Contractual Relationships between General Contractors and Specialist Sub-Contractors in the Building Industry Post-Graduate Research Project.	Philip, J. Greenacre, Montreal 1961.
10.	A Study of the Application of Network Analysis in the Building Industry, unpublished M.Sc. Thesis 1965.	A. T. Pollock
11.	Functions of Supervisors	Hans Wirdenuis and Sterner Lonnsjo

12.	A Study of Site Manager, unpublished M.Sc. Thesis	C. Reynaud
13.	New Patterns of Management	Lickert Rensis
14.	Managing for Results	Peter Drucker
15.	Standards for Morale, Cause and Effect	R. W. Revans
16.	The Theory of Practice in Management.	R. W. Revans
17.	The Hospital as an Organism. Proceedings of the Second Conference on Operations Research, organised by the International Federation of O. R. Society	R. W. Revans
18.	Measurement of Values	Thurstone, Louis Leon
19.	Some Application of Behavioural Sciences	Lickert Rensis Hayes, Samuels P.
20.	Systems, Organisation and Inter-disciplinary Research - Systems Research Design	R. L. Ackoff
21.	The Application of Operations Research Techniques to Building Operations, B.R.S. Note No. E.1132	J. F. Nuttal
22.	Study of Decision Rules for Site Control, Builder 20 August 1965.	J. F. Nuttal
23.	The Study of Operations and Economies at The Building Research Station, The Chartered Surveyor, April 1962.	W. J. Reiners
24.	Mechanisation and Building Process Structural Construction, March/ April 1962.	D. Bishop
25.	Incentives in Building Industry 1959.	D.S.I.R.

26.	Building Economics: Cost Planning, April 1958.	B.R.S.
27.	Cranes for Building, December 1959.	B.R.S.
28.	Programming of House Building, Digest No. 91.	B.R.S.
29.	Discriminant Model for the Analysing of Factors Influencing Innovation in Industry. Ph.D. Thesis Jan. 1965.	M. I. Hussain
30.	Rank Correlation Methods	M. G. Kendal
31.	Advanced Theory of Statistics	M. G. Kendal and Stuart
32.	A Course in Multivariate Analysis	M. G. Kendal
33.	Introduction to Matrix Analysis	Richard Bellaman
34.	The Approximate Solution of Matrix Problems, J. Assoc. Comp. March 1958.	A. S. Householder
35.	Work Load and the use of Materials, Builder 14 May 1965.	Gordon Bayley
36.	Industrial Dynamics	J. W. Forrester
37.	Contract Management in the Building Industry.	London School of Economics

Actual Distribution of Projects by Value

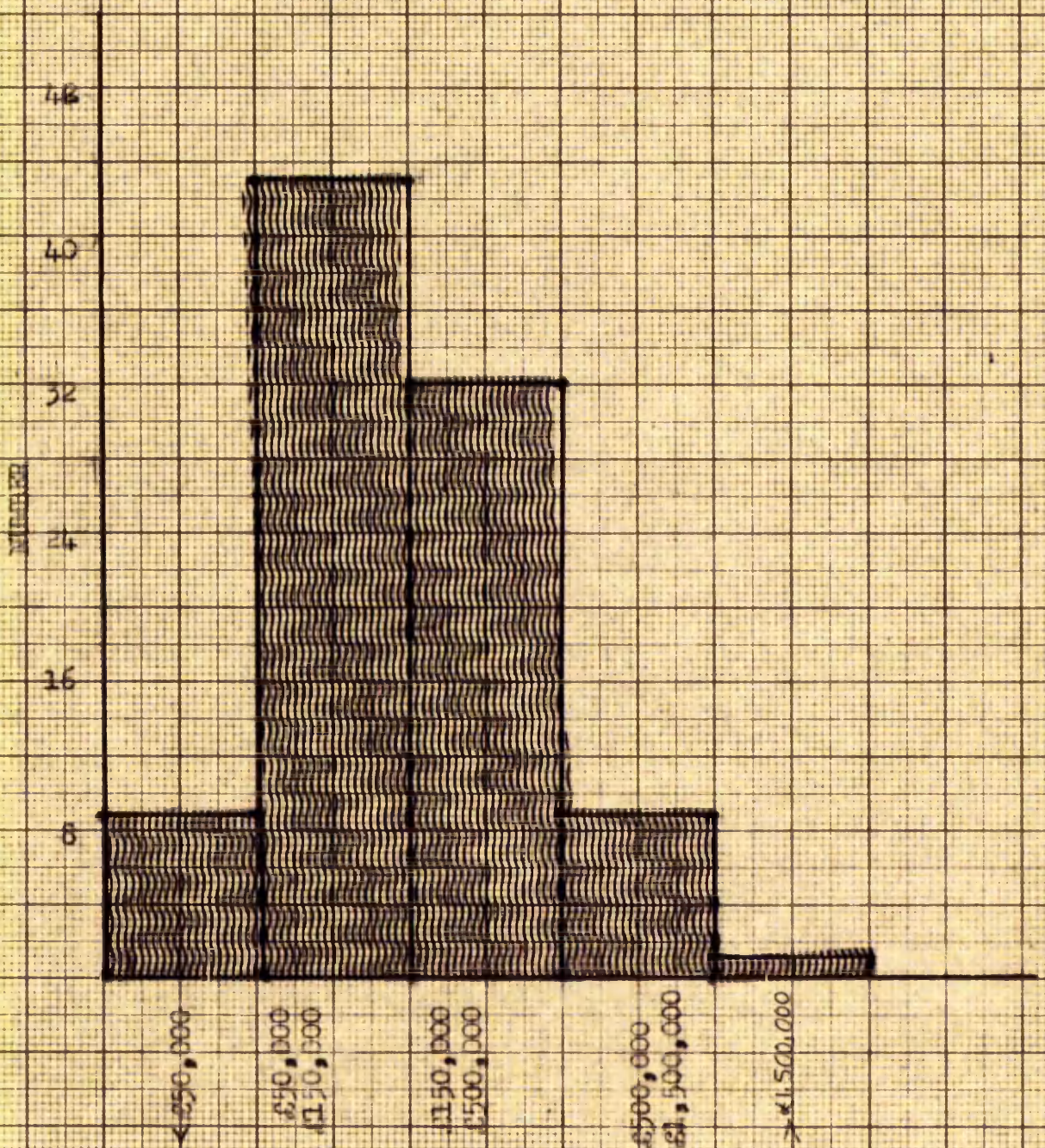
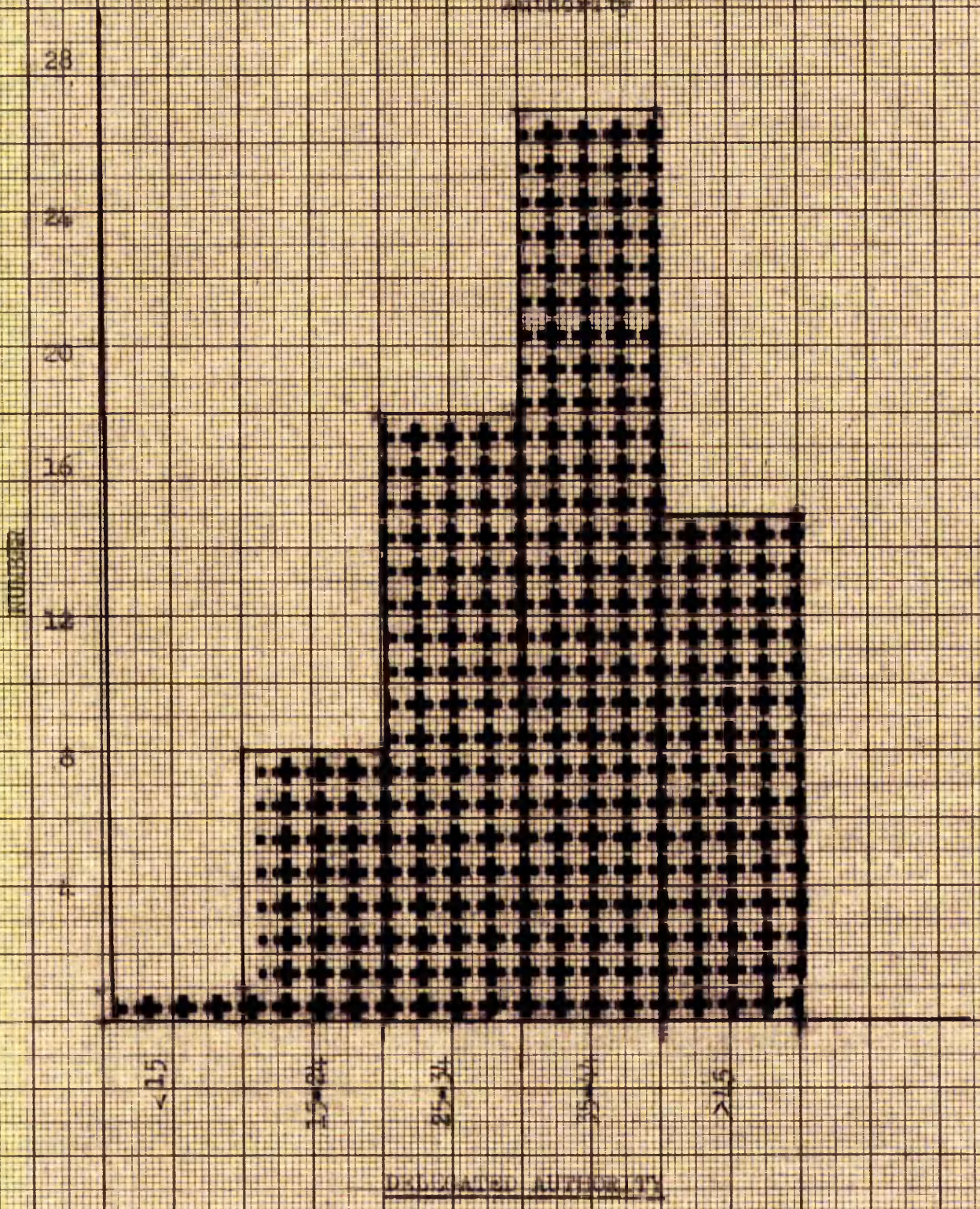


Fig. 1

Actual Distribution of Bids by Delegated Authority



DELEGATED AUTHORITY

Fig. 6

Actual Distribution by No. Removed from Board

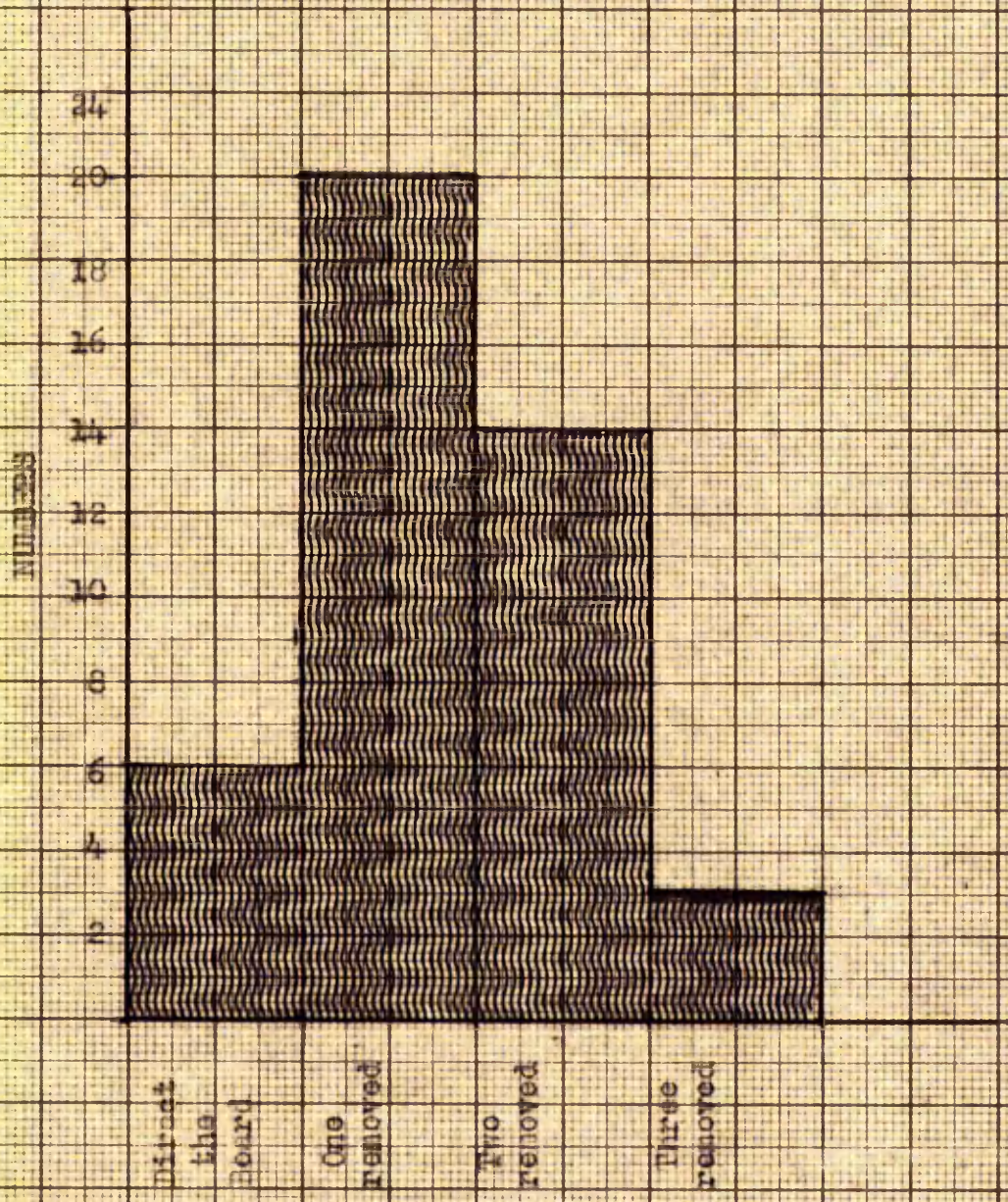


Fig. 7

SITE MANAGER -

Actual Distribution by Designation on Site

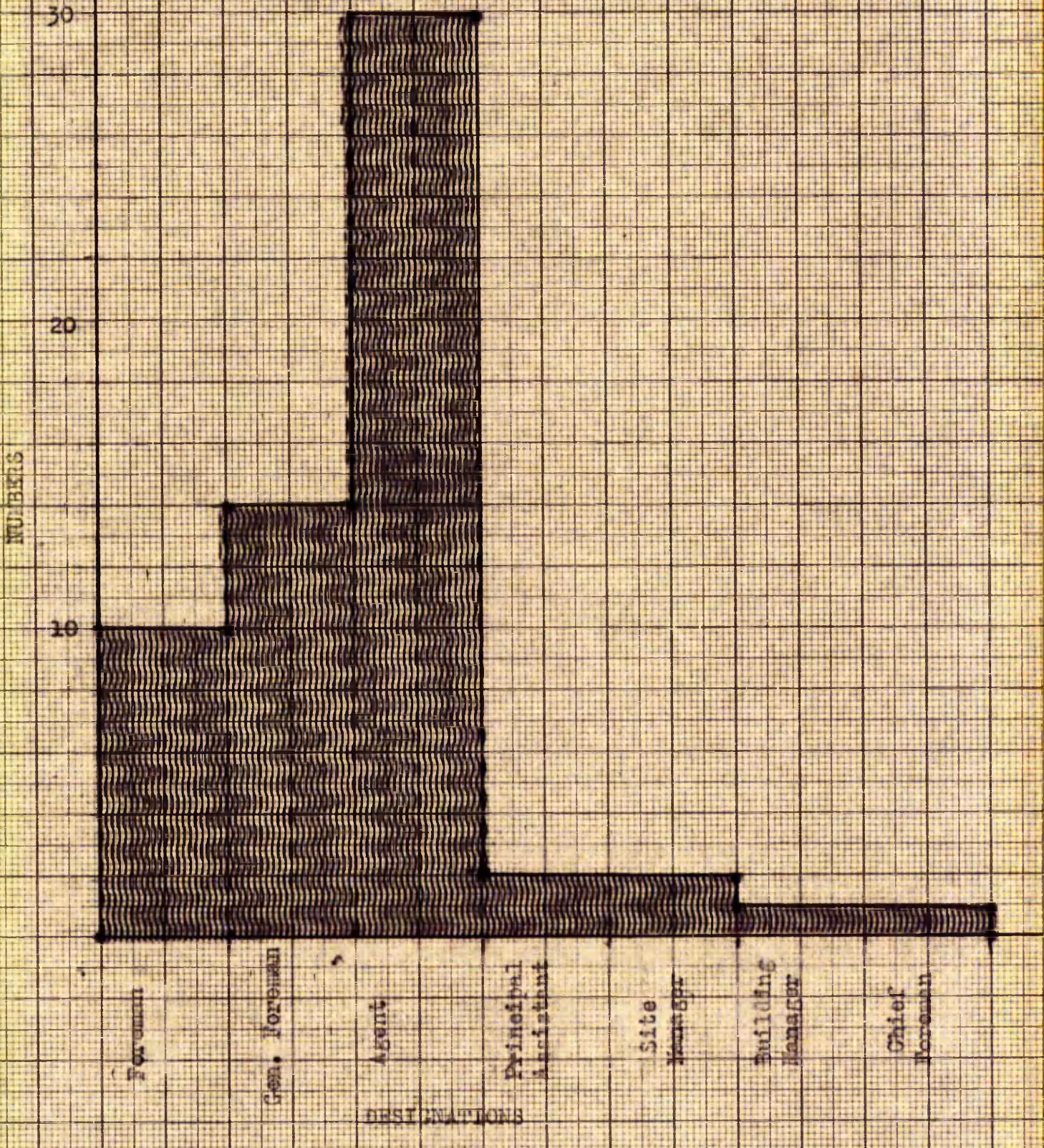


Fig. 8

Distribution by Actual Number

Technical Qualifications of Site Managers

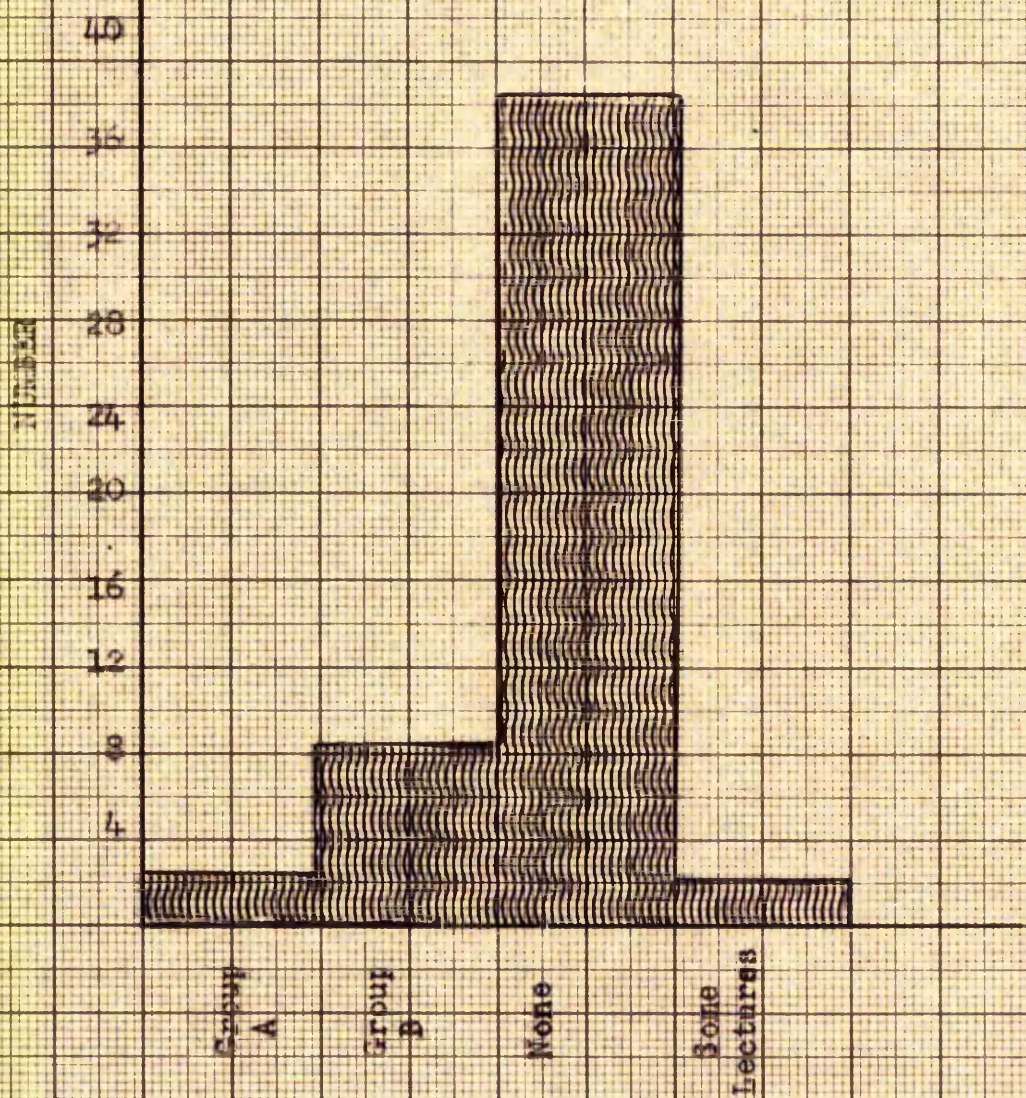


FIG. 2

Actual Distribution by Age of Site Members

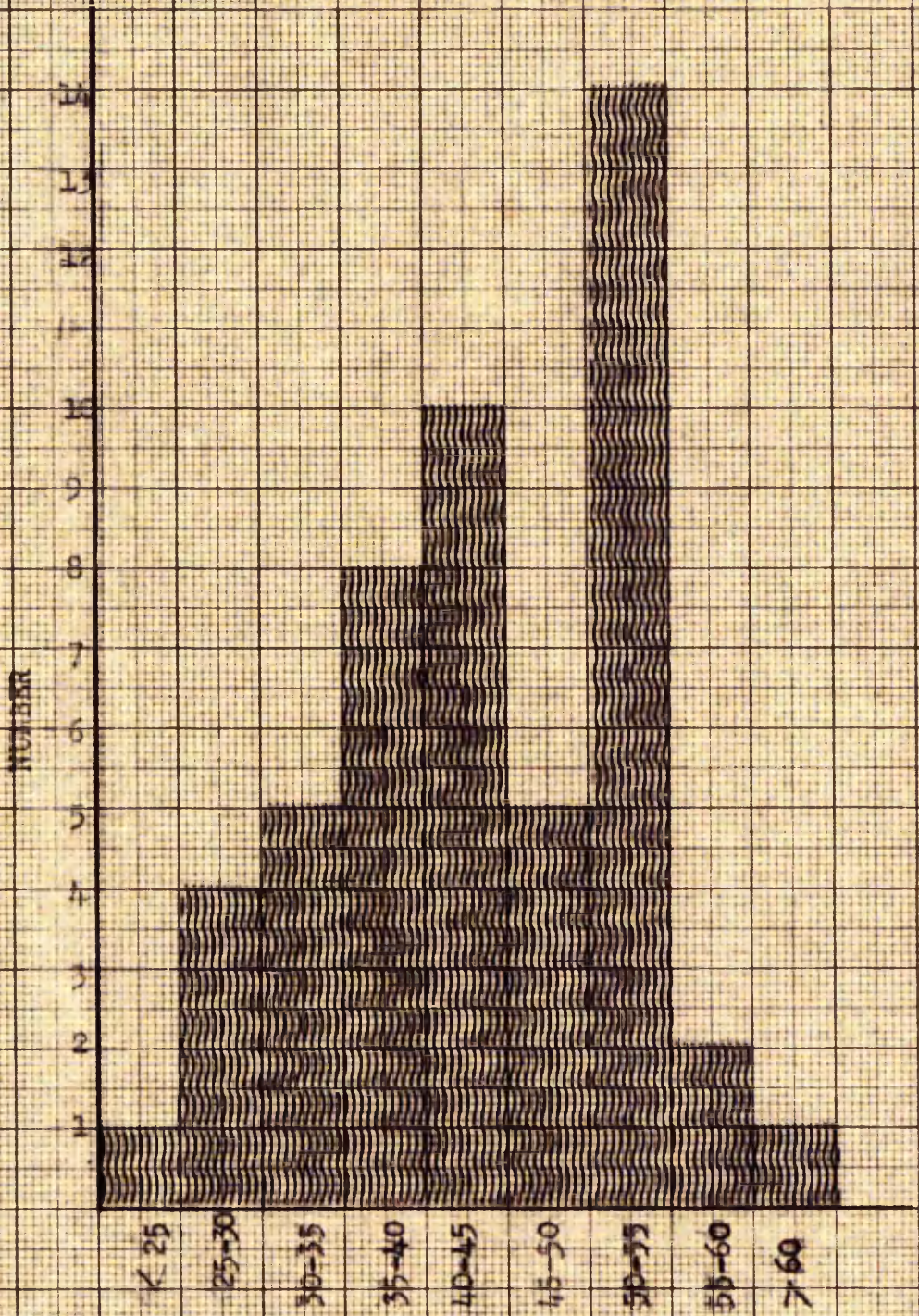


FIG. 10

APPENDIX TABLE 1

		1	2	3	4	5	6	7	8	9
No:	PROJECT / AUTHORITY	P301	P281	P205	P456	P16	P17	P44	P372	P3
1	a	3	3	5	6½	3	4	4½	2	4
2	b	5	2	2	2	1	1	2	5	2
3	c	1	5	3	6½	7	7	4½	6	6
4	d	8	6	6	3½	2	5	6½	3	5
5	e	9	7	7	3½	5	6	6½	4	7
6	f	2	8	8	9	10	8	9	8	8
7	g	6	9	10	9	8	9	9	9	9
8	h	7	10	9	9	9	10	9	10	10
9	i	4	1	1	1	6	3	1	7	1
10	j	10	4	4	5	4	2	3	1	3

		10	11	12	13	14	15	16	17	18
No	PROJECT / AUTHORITY	P166	P294	P56	P356	P369	P8	P435	P355a	P230
1	a	6	3	5	4	3	3	2	3	6
2	b	2	2	3	1	4	2	3	1	2
3	c	4	4	2	2	5	4	7	5	7
4	d	5	8	6	3	6	5	5	7	4
5	e	7	9	7	9	7	6	6	8	3
6	f	9	6	9	5	9	8	10	9	9
7	g	8	5	8	7	8	9	8	10	1
8	h	10	7	10	8	10	10	9	4	8
9	i	1	1	1	6	2	1	1	2	1
10	j	3	10	4	10	1	7	4	6	5

		19	20	21	22	23	24	25	26
No:	PROJECT / AUTHORITY	P6	P36	P80	P229	P323			
1	a	10	3	2	3	3	3	5	2
2	b	2	2	1	5	7	2	2	1
3	c	3	7	6	4	6	5	4	7
4	d	5	4	3	2	1	8	7	5
5	e	6	5	4	7	2	9	10	6
6	f	8	8	10	9	4	6	8	8
7	g	9	10	9	8	9	10	6	9
8	h	7	9	8	10	8	7	9	10
9	i	1	1	7	1	5	1	1	3
10	j	4	6	5	6	10	4	3	4

APPENDIX TABLE * 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.000	.200	.236	-.212	-.309	-.151	.078	-.333	.030	.030	.733	.248	.648	-.042	.345	-.080	.224	-.248	-.030	.042	-.212	.175	.139	.381	.260	.018
2	.200	1.000	.939	.769	.660	.903	.963	.551	.975	.915	.551	.903	.381	.903	.927	.915	.721	.757	.612	.890	.600	.806	.103	.866	.842	.927
3	.236	.939	1.000	.769	.551	.818	.963	.442	.915	.939	.503	.951	.418	.830	.890	.781	.745	.757	.806	.806	.515	.757	.042	.854	.830	.793
4	-.212	.769	.769	1.000	.733	.793	.818	.515	.818	.818	.224	.721	.224	.648	.806	.793	.515	.975	.733	.890	.660	.745	.357	.478	.490	.769
5	-.309	.660	.551	.733	1.000	.818	.660	.781	.709	.636	.078	.515	.357	.636	.636	.751	.466	.696	.333	.745	.951	.636	.260	.359	.406	.842
6	-.151	.903	.818	.793	.818	1.000	.890	.721	.951	.866	.236	.745	.224	.878	.757	.866	.587	.793	.575	.842	.721	.648	.042	.721	.721	.951
7	.078	.963	.963	.818	.660	.890	1.000	.563	.951	.951	.442	.939	.289	.915	.878	.890	.733	.806	.733	.842	.612	.769	.018	.818	.830	.866
8	-.333	.551	.442	.515	.781	.721	.563	1.000	.600	.490	-.272	.430	.030	.709	.430	.612	.163	.478	.127	.539	.757	.527	.289	.272	.248	.696
9	.030	.975	.915	.818	.709	.951	.951	.600	1.000	.939	.418	.866	.296	.915	.866	.915	.660	.806	.660	.890	.600	.793	.078	.818	.830	.927
10	.030	.915	.939	.818	.636	.866	.951	.490	.939	1.000	.406	.951	.321	.878	.830	.818	.600	.769	.818	.769	.515	.781	-.054	.721	.878	.793
11	.733	.551	.503	.224	.078	.236	.442	-.272	.418	.406	1.000	.515	.624	.260	.660	.430	.612	.212	.248	.454	.090	.442	.006	.624	.612	.406
12	.248	.903	.951	.721	.515	.745	.939	.430	.866	.951	.515	1.000	.393	.854	.866	.769	.612	.660	.757	.709	.454	.806	-.018	.733	.866	.721
13	.648	.381	.418	.224	.357	.224	.284	.030	.296	.321	.624	.393	1.000	.090	.575	.187	.393	.139	.236	.369	.393	.466	.321	.345	.345	.369
14	-.042	.903	.830	.648	.636	.878	.915	.709	.915	.878	.260	.854	.090	1.000	.721	.878	.539	.624	.515	.709	.539	.733	-.090	.733	.818	.830
15	.345	.927	.890	.806	.636	.757	.878	.430	.866	.830	.660	.866	.575	.721	1.000	.842	.696	.769	.587	.915	.624	.866	.357	.745	.696	.854
16	-.066	.915	.781	.793	.751	.866	.890	.612	.915	.818	.430	.769	.187	.878	.842	1.000	.684	.793	.454	.903	.684	.818	.151	.709	.709	.915
17	.224	.721	.745	.515	.466	.587	.733	.163	.660	.600	.612	.612	.393	.539	.696	.684	1.000	.600	.527	.696	.527	.490	-.066	.842	.624	.660
18	-.248	.757	.757	.975	.696	.793	.806	.478	.806	.769	.212	.660	.139	.624	.769	.793	.600	1.000	.721	.903	.648	.660	.321	.539	.454	.769
19	-.030	.612	.806	.733	.333	.575	.733	.127	.660	.818	.248	.757	.236	.515	.587	.454	.527	.721	1.000	.539	.248	.490	-.115	.539	.636	.430
20	.042	.890	.806	.890	.745	.842	.842	.539	.890	.769	.454	.709	.369	.709	.915	.903	.696	.903	.539	1.000	.709	.806	.430	.709	.563	.915
21	-.212	.660	.515	.660	.951	.721	.612	.757	.600	.515	.090	.454	.393	.539	.624	.684	.527	.648	.248	.709	1.000	.551	.333	.345	.272	.793
22	.175	.806	.757	.745	.636	.648	.769	.527	.793	.781	.442	.806	.466	.733	.866	.818	.490	.660	.490	.806	.551	1.000	.418	.539	.624	.721
23	.139	.103	.042	.357	.260	.042	.018	.284	.078	-.054	.006	-.018	.321	-.090	.357	.151	-.066	.321	-.115	.430	.333	.418	1.000	-.103	-.357	.212
24	.381	.866	.854	.478	.357	.721	.818	.272	.818	.721	.624	.733	.345	.733	.745	.709	.842	.539	.539	.709	.345	.539	-.103	1.000	.806	.745
25	.260	.842	.830	.490	.406	.721	.830	.248	.830	.878	.612	.866	.345	.818	.696	.709	.624	.454	.636	.563	.272	.624	-.357	.806	1.000	.6721
26	.018	.927	.793	.769	.842	.951	.866	.696	.927	.793	.406	.721	.369	.830	.854	.915	.660	.769	.430	.915	.793	.721	.212	.745	.6721	1.000

APPENDIX TABLE 3a

INDEX OF DELEGATED AUTHORITY

	Project	a	b	c	d	e	f	g	h	i	j	
	Ref. No.	7:3	8:3	6:2	5:2:0	4:2:0	2:1:0	2:1:0	2:1:0	10→0	6:4:2:0	I,
1	P/2	3	8	6	5	4	0	1	2	10	0	39
2	P/3	7	8	2	5	4	1	1	1	6	2	37
3	P/6	7	8	6	5	4	2	2	2	10	4	50
4	P/7	7	8	2	5	4	1	1	1	10	4	43
5	P/8	7	8	6	2	4	0	0	0	0	5	31
6	P/10	7	8	6	5	4	1	2	1	0	4	38
7	P/11	7	8	6	5	4	1	2	2	10	6	51
8	P/14	7	8	2	2	2	0	0	0	8	4	33
9	P/16	3	8	6	0	2	0	0	0	6	4	29
10	P/17	3	8	6	5	4	1	1	1	10	4	43
11	P/24	3	8	2	5	4	0	2	1	10	4	39
12	P/28	7	8	6	5	4	1	1	1	2	2	37
13	P/29	7	8	6	5	4	2	2	2	0	4	40
14	P/36	7	8	8	5	4	2	2	2	10	6	52
15	P/38	7	8	6	2	2	0	0	0	0	2	27
16	P/42	7	8	6	5	4	1	2	1	-	4	38
17	P/46	3	3	2	2	2	0	2	1	0	2	17
18	P/54	7	8	6	5	4	1	2	1	10	4	48
19	P/56	7	8	6	5	2	0	1	1	10	4	44
20	P/62											
21	P/67	7	8	2	5	4	0	0	0	0	4	30
22	P/80	7	3	2	5	4	1	1	1	0	4	29
23	P/83	3	3	6	5	4	1	2	1	2	4	31
24	P/87	7	8	6	5	4	1	2	1	0	4	38
25	P/98	3	3	6	2	2	0	0	0	10	4	30

APPENDIX TABLE 3a (continued)

	Project	a	b	c	d	e	f	g	h	i	j	
	Ref. No.	7:3	8:3	6:2	5:2:0	4:2:0	2:1:0	2:1:0	2:1:0	10 0	6:4:2:0	I_1
26	P/119	7	8	6	5	4	0	1	1	0	6	38
27	P/152	3	3	2	2	2	0	0	0	0	4	16
28	P/166	7	8	5	2	4	0	2	1	0	2	32
29	P/189	7	8	6	5	4	2	2	2	10	6	52
30	P/197	7	3	2	5	4	0	0	0	4	0	26
31	P/198	7	8	6	5	4	1	2	1	1	4	38
32	P/205	9	8	6	5	4	0	1	0	2	4	37
33	P/207	7	8	6	5	4	2	2	2	10	4	50
34	P/212	7	8	6	2	2	1	1	1	4	4	36
35	P/229	3	3	2	2	2	0	0	0	0	4	16
36	P/232	7	8	2	2	4	1	2	1	2	4	33
37	P/281	7	8	6	5	4	0	2	1	0	4	37
38	P/288	7	8	2	5	4	0	0	0	6	4	36
39	P/290	3	3	2	2	4	0	0	0	0	0	14
40	P/294	3	3	6	2	2	0	1	1	0	2	20
41	P/301	3	8	6	0	0	0	0	0	0	0	17
42	P/323	3	3	2	0	0	0	0	0	10	0	18
43	P/328	7	8	2	5	4	0	2	1	0	4	33
44	P/329	7	8	6	5	4	1	1	1	2	4	39
45	P/334	7	8	6	5	4	0	2	0	10	4	46
46	P/339	7	8	6	5	4	1	2	1	0	4	38
47	P/343	7	8	2	5	2	0	0	0	4	4	32
48	P/355c	7	8	6	5	4	2	2	2	10	4	50
49	P/356	7	3	6	0	0	0	0	0	0	2	18
50	P/359	7	8	6	5	4	1	2	1	6	4	44

APPENDIX TABLE 3a (continued)

	Project Ref.No.	a 7:3	b 8:3	c 6:2	d 5:2:0	e 4:2:0	f 2:1:0	g 2:1:0	h 2:1:0	i 10 0	j 6:4:2:0	I_1
51	P/369	7	8	6	5	4	0	0	2	6	6	44
52	P/392	7	8	6	5	4	-	-	-	10	4	44
53	P/393	7	8	6	5	4	-	-	-	0	4	34
54	P/435	7	8	6	5	4	2	2	2	8	4	48
55	P/443	7	8	6	5	4	1	2	1	0	4	38
56	P/456	7	8	6	2	2	0	0	0	0	4	29
57	P/467	7	8	2	5	4	1	1	0	0	4	32
58	P/489	7	8	6	5	4	2	2	2	10	4	50
59	P/493	3	8	2	2	2	1	2	1	0	4	25
60	P/498	7	8	2	5	4	1	1	1	2	6	37
61	P/510	3	8	2	2	2	0	0	0	0	4	21
62	P/516	7	8	6	5	4	2	2	2	6	4	46
63	P/517	7	3	6	5	4	0	0	0	0	4	29
64	P/520	7	8	6	5	4	-	-	-	0	6	36
65	P/521	7	8	6	5	4	1	2	1	10	4	48
66	P/526	7	8	6	5	4	1	2	1	10	4	48
67	P/527	7	8	6	5	4	1	2	1	10	4	48
68	P/528	7	3	6	5	4	1	1	1	6	4	38
69	P/529	7	8	6	5	4	0	2	0	0	4	36
70	P/530	7	8	6	5	4	1	2	1	10	4	48

APPENDIX TABLE 3.b

INDEX OF EXERCISED AUTHORITY

	Project	a	b	c	d	e	f	g	h	i	j	
	Ref.No.	7:3	8:3	6:2	5:2:0	4:2:0	2:1:0	2:1:0	2:1:0	10→0	6:4:2:0	I_z
1	P/2	5	8	4	4	3	0	0	0	10	4	38
2	P/3	7	8	2	4	3	0	0	0	6	4	34
3	P/6	7	8	6	5	4	0	0	0	10	6	46
4	P/7	5	8	6	4	3	1	0	1	10	4	42
5	P/8	4	0	2	5	4	1	1	1	0	6	24
6	P/10						N.A.			0		
7	P/11	7	5	2	4	3	0	0	1	10	6	38
8	P/14						N.A.			8		
9	P/16	7	3	6	0	0	0	0	0	6	6	28
10	P/17	7	3	6	4	3	0	0	0	10	4	37
11	P/24	5	0	6	5	4	0	0	0	10	6	36
12	P/28	4	5	3	2	2	0	0	0	2	3	21
13	P/29	3	8	6	5	4	1	1	0	0	6	34
14	P/36	3	8	0	2	2	0	0	0	10	6	31
15	P/38	3	5	2	2	2	0	0	0	0	6	20
16	P/42						N.A.			0		
17	P/46	3	3	1	2	2	0	0	0	0	2	13
18	P/54	5	3	2	2	2	0	0	0	10	2	26
19	P/56	5	0	6	5	4	1	1	1	10	6	39
20	P/62						N.A.					
21	P/67	3	8	0	0	0	0	0	0	0	2	13
22	P/80	7	1	1	5	4	0	0	0	0	6	24
23	P/83	3	0	2	1	1	0	0	0	2	2	11
24	P/87	5	2	3	3	2	0	0	0	0	4	19
25	P/98	3	3	6	5	4	0	0	2	10	2	35

APPENDIX TABLE 3.b (continued)

	Project Ref. No	a 7:3	b 8:3	c 6:2	d 5:2:0	e 4:2:0	f 2:1:0	g 2:1:0	h 2:1:0	i 10 0	j 6:4:2:0	T_2
26	P/119						N.A.			0		
27	P/152	7	1	2	2	2	0	0	0	0	2	16
28	P/166	5	5	6	5	4	0	0	0	0	2	27
29	P/184	5	8	6	5	4	0	0	0	10	1	39
30	P/188	4	8	6	5	4	1	1	0	5	6	40
31	P/198						N.A.					
32	P/205	4	3	4	3	2	0	0	0	2	4	22
33	P/207	4	8	4	3	2	1	0	0	10	6	33
34	P/212	3	8	6	2	2	1	1	0	4	6	33
35	P/229	4	3	2	3	2	0	0	0	2	6	22
36	P/232	3	8	2	2	1	0	1	0	2	2	21
37	P/281	7	3	4	2	2	0	0	0	0	2	20
38	P/288	7	8	6	5	4	0	1	1	6	6	44
39	P/290	3	4	1	2	1	0	0	0	0	2	13
40	P/294	3	2	3	3	2	0	0	0	0	3	16
41	P/301	3	8	3	2	2	0	0	0	0	N.A.	18
42	P/323	3	4	3	2	2	0	2	1	10	0	27
43	P/328	5	8	2	4	3	0	0	0	0	4	26
44	P/329	3	4	6	3	2	0	0	0	2	4	24
45	P/334	5	2	2	5	4	1	0	1	10	4	34
46	P/339	5	3	2	4	3	0	0	0	0	6	23
47	P/343	3	4	6	2	2	0	0	0	4	3	24
48	P/355c	3	8	6	2	2	0	0	0	10	6	37
49	P/356	3	3	2	2	2	0	0	0	0	2	14
50	P/359	4	8	6	5	4	0	0	0	6	3	36

APPENDIX TABLE 3b (continued)

	Project Ref. No.	a 7:3	b 8:3	c 6:2	d 5:2:0	e 4:2:0	f 2:1:0	g 2:1:0	h 2:1:0	i 10 0	j 6:4:2:0	I_2
51	P/369	3	4	6	2	2	0	0	0	6	3	36
52	P/377	7	2	1	3	3	0	0	0	0	N.A.	N.A.
53	P/392	4	4	2	3	3	0	0	0	10	3	29
54	P/393	4	2	2	3	3	0	0	0	3	3	17
55	P/413	5	6	6	3	3	0	0	0	0	4	27
56	P/456	3	4	6	3	3	0	0	0	0	2	21
57	P/467	5	6	2	2	2	0	0	0	0	3	20
58	P/481	5	8	6	5	4	0	0	0	2	6	36
59	P/491	3	8	3	5	4	0	0	0	0	4	27
60	P/510	3	3	3	2	2	0	0	0	0	3	16
61	P/517	7	2	6	5	4	0	0	0	0	6	30
62	P/520	8					N. A.					
63	P/521	5	6	2	4	3	0	0	0	10	4	34
64	P/526	5	8	2	3	3	0	0	0	10	4	35
65	P/527	3	8	3	4	3	0	0	0	10	6	37
66	P/528	4	0	2	1	1	0	1	0	6	0	15
67	P/529	7	8	4	4	3	0	0	0	0	6	32
68	P/530	4	6	4	4	3	0	0	0	10	3	34

APPENDIX TABLE 4

		Items								
	Project Ref.No.	1	2	3	4	5	6	7	8	9
1	P56	6	6	6	6	6	6	2	6	2
2	P11	6	8	8	6	6	6	6	2	2
3	P14	6	8	4	6	6	4	4	2	0
4	P24	6	8	8	2	2	0	4	2	0
5	P28	2	6	0	6	8	6	0	0	0
6	P29	6	6	6	6	2	6	2	6	2
7	P54	2	6	6	6	6	2	2	2	4
8	P6	2	8	8	0	4	6	6	2	2
9	P87	8	8	2	8	8	8	0	2	0
10	P188	2	8	8	8	8	2	0	8	8
11	P198	6	8	8	6	2	4	6	2	2
12	P207	2	8	6	6	6	6	8	2	6
13	P232	6	8	8	6	2	6	6	2	0
14	P290	2	6	6	2	6	4	6	2	2
15	P339	2	4	6	6	6	6	2	2	2
16	P359	2	8	0	8	8	8	2	2	8
17	P467	2	8	4	8	8	0	0	0	0
18	P491	6	6	8	2	2	6	6	8	0
19	P520	2	6	8	2	6	2	6	2	2
20	P527	2	6	6	2	6	6	4	6	2
21	P529	2	8	4	2	2	0	2	6	2
22	P528	6	8	6	8	8	4	8	0	0
23	P36	6	8	6	6	6	6	6	2	2
24	P435	2	6	6	6	6	6	6	2	0
25	P323	2	6	6	6	6	8	6	2	2
26	P456	6	6	6	2	2	6	6	2	0
27	P294	2	8	8	4	2	6	6	6	0
28	P516	8	8	6	2	2	0	8	0	6

APPENDIX TABLE 4 (continued)

		Items								
	Project Ref.No.	10	11	12	13	14	15	16	17	18
1	P56	6	0	0	2	6	6	6	6	6
2	P11	2	2	6	8	6	4	6	6	2
3	P14	2	2	2	2	6	8	6	0	6
4	P24	8	2	0	0	2	4	4	6	6
5	P28	8	0	6	0	0	6	2	2	2
6	P29	6	2	2	2	2	8	2	2	6
7	P54	2	2	2	4	4	4	8	2	2
8	P6	6	2	2	0	8	8	8	6	8
9	P87	6	0	0	2	8	0	0	8	0
10	P188	6	0	4	8	8	8	8	8	2
11	P198	6	4	0	0	8	6	8	0	6
12	P207	8	0	0	4	6	6	2	6	2
13	P232	8	0	2	0	8	4	6	6	8
14	P290	2	2	2	2	2	2	2	6	2
15	P339	6	0	6	6	8	2	4	2	2
16	P359	0	0	6	4	6	6	2	6	2
17	P467	0	6	0	0	2	6	8	0	0
18	P491	8	0	2	0	8	6	8	2	8
19	P520	6	2	0	0	6	6	6	2	6
20	P527	8	0	0	0	6	8	6	2	8
21	P529	6	0	6	2	4	8	8	6	8
22	P528	4	6	2	0	2	6	8	2	2
23	P36	2	2	2	0	6	2	6	6	6
24	P435	4	2	0	2	6	6	6	2	6
25	P323	2	0	2	2	8	8	2	2	2
26	P456	6	0	2	4	6	6	8	6	8
27	P294	6	0	0	6	2	6	6	4	8
28	P516	2	0	0	0	8	8	8	0	6

APPENDIX TABLE 4 (continued)

		Items								
	Project Ref.No.	19	20	21	22	23	24	25	26	27
1	P56	2	6	2	6	6	6	6	6	0
2	P11	8	6	6	8	4	8	6	6	6
3	P14	6	6	6	6	6	6	4	6	2
4	P24	2	0	0	8	8	8	0	8	0
5	P28	0	0	2	6	6	6	8	6	6
6	P29	2	2	6	8	2	6	2	2	6
7	P54	2	6	0	2	2	2	6	6	0
8	P6	2	4	6	8	6	8	8	6	2
9	P87	6	2	8	6	2	8	2	0	6
10	P188	8	2	8	2	0	8	2	4	8
11	P198	6	2	6	8	2	6	6	6	0
12	P207	2	6	2	2	8	6	4	6	2
13	P232	6	6	6	8	2	8	6	8	2
14	P290	2	2	2	4	6	6	6	6	2
15	P339	4	2	2	8	6	6	6	2	6
16	P359	6	2	8	8	8	2	6	6	6
17	P467	8	2	0	0	8	6	8	6	8
18	P491	8	8	8	8	8	8	8	6	0
19	P520	6	6	6	6	2	8	6	6	0
20	P527	2	2	2	2	4	6	8	8	0
21	P529	8	0	6	4	6	6	6	6	6
22	P528	8	6	0	6	2	8	2	0	6
23	P36	6	6	6	8	6	6	6	6	2
24	P435	6	6	0	4	8	8	6	4	2
25	P323	2	6	6	8	2	8	6	6	2
26	P456	6	8	2	6	2	6	6	6	2
27	P294	6	6	6	4	8	8	6	6	0
28	P516	6	8	0	6	2	4	2	4	0

APPENDIX TABLE 4 (continued)

		Items					
	Project Ref. No.	28	29	30	31	32	33
1	P56	6	6	6	6	8	0
2	P11	6	8	6	8	8	0
3	P14	2	6	6	6	8	2
4	P24	8	4	2	6	4	2
5	P28	8	4	8	6	8	0
6	P29	6	6	2	0	8	0
7	054	0	6	0	4	6	6
8	P6	4	2	2	8	8	0
9	P87	0	8	6	6	0	0
10	P188	8	8	8	0	0	0
11	P198	6	6	6	8	6	2
12	P207	8	4	0	2	4	2
13	P232	2	2	4	6	8	0
14	P290	4	6	6	6	6	4
15	P339	4	6	6	2	6	4
16	P359	6	6	8	4	8	4
17	P467	0	8	8	6	4	6
18	P491	0	2	6	6	8	8
19	P520	6	2	6	2	2	2
20	P527	2	0	6	6	6	0
21	P529	6	6	8	2	2	0
22	P528	6	6	6	0	6	8
23	P36	2	8	2	6	8	0
24	P435	8	4	4	8	6	0
25	P323	8	6	0	6	6	2
26	P456	2	2	2	6	2	0
27	P294	8	2	8	4	6	6
28	P516	0	2	6	6	2	0

APPENDIX TABLE NO. 5.

CORRELATION MATRIX

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.000	0.207	0.118	0.055	-0.338	0.000	0.204	-0.085	-0.250	0.051	0.076	-0.243
2	0.207	1.000	0.000	0.121	0.025	-0.237	0.179	-0.199	0.147	-0.180	0.200	-0.107
3	0.118	0.000	1.000	-0.387	-0.507	-0.170	0.543	0.307	-0.084	0.279	0.125	-0.365
4	0.055	0.121	-0.387	1.000	0.607	0.286	-0.401	-0.173	0.156	-0.325	0.235	0.170
5	-0.338	0.025	-0.507	0.607	1.000	0.224	-0.394	-0.283	0.213	-0.379	0.195	0.204
6	0.000	-0.237	-0.170	0.286	0.224	1.000	0.037	0.148	-0.026	0.134	-0.398	0.167
7	0.204	0.179	0.543	-0.401	-0.394	0.037	1.000	-0.213	-0.072	0.006	0.113	-0.341
8	-0.085	-0.199	0.307	-0.173	-0.283	0.148	-0.213	1.000	0.134	0.415	-0.427	0.029
9	-0.250	0.147	-0.084	0.156	0.213	-0.026	-0.072	0.134	1.000	-0.242	-0.287	0.229
10	0.051	-0.180	0.279	-0.325	-0.379	0.134	0.006	0.415	-0.242	1.000	-0.387	-0.132
11	0.076	0.200	0.125	0.235	0.195	-0.398	0.113	-0.427	-0.287	-0.387	1.000	-0.235
12	-0.243	-0.107	-0.365	0.170	0.204	0.167	-0.341	0.029	0.229	-0.132	-0.235	1.000
13	-0.239	-0.047	0.083	0.299	0.176	0.250	-0.190	0.284	0.401	-0.135	-0.318	0.437
14	0.232	0.113	0.268	-0.044	-0.103	0.337	0.230	0.145	0.269	0.087	-0.374	-0.053
15	-0.212	0.027	0.080	-0.217	-0.213	-0.172	0.097	0.295	0.229	0.056	-0.031	-0.031
16	0.078	0.252	0.483	-0.262	-0.306	-0.490	0.226	0.150	-0.049	-0.045	0.320	-0.108
17	0.026	0.293	0.020	-0.015	0.064	0.284	-0.124	0.253	0.218	0.207	-0.400	0.212
18	0.190	-0.021	0.444	-0.670	-0.771	-0.070	0.385	0.414	-0.270	0.437	-0.239	-0.265
19	0.262	0.461	0.128	0.206	-0.036	-0.199	0.097	0.097	-0.025	-0.254	0.246	0.108
20	0.308	0.023	0.391	-0.105	-0.187	0.163	0.656	-0.056	-0.049	-0.163	-0.064	-0.317
21	0.114	0.180	0.024	0.096	-0.077	0.451	-0.140	0.493	0.150	0.090	-0.341	0.258
22	0.492	-0.096	0.102	-0.106	-0.337	0.361	0.250	-0.112	-0.181	0.088	-0.121	0.253
23	-0.302	0.068	-0.209	-0.133	0.016	0.010	-0.009	0.017	-0.167	-0.028	-0.014	0.026
24	0.117	0.193	0.490	-0.119	-0.103	0.161	0.237	0.188	-0.518	0.442	0.076	-0.201
25	-0.482	-0.212	-0.082	-0.207	0.068	0.237	-0.015	0.037	-0.199	-0.045	-0.061	0.186
26	-0.270	0.237	0.187	-0.417	-0.233	-0.167	0.171	0.049	0.000	0.071	-0.191	-0.062
27	-0.168	0.042	-0.510	0.571	0.498	0.060	-0.597	-0.073	0.136	-0.191	0.164	0.570
28	-0.369	0.022	-0.005	0.227	0.168	0.182	-0.076	0.101	0.163	0.220	-0.097	0.152
29	0.085	0.129	-0.287	0.597	0.503	-0.007	-0.457	-0.112	0.160	-0.520	0.338	0.320
30	-0.184	-0.185	-0.320	0.176	0.253	-0.230	-0.444	0.169	0.051	-0.127	0.047	0.304
31	-0.155	0.119	0.023	-0.240	-0.144	0.141	0.191	-0.287	-0.355	-0.143	0.010	-0.241
32	-0.193	0.092	-0.113	0.077	-0.032	0.409	0.134	-0.024	-0.217	-0.111	0.115	0.210
33	-0.149	0.000	0.078	0.141	0.070	-0.153	0.123	-0.044	0.117	-0.213	139	-0.077

APPENDIX NO. 5. (Contd.)

	13	14	15	16	17	18	19	20	21	22	23	24	
1	-0.239	0.232	-0.212	0.078	0.026	0.190	0.262	0.308	0.114	0.492	-0.302	0.117	1
2	-0.047	0.113	0.097	0.252	0.293	-0.021	0.461	0.023	0.180	-0.096	0.088	0.103	2
3	0.083	0.268	0.020	0.483	0.020	0.444	0.128	0.391	0.024	0.102	-0.209	0.490	3
4	0.299	-0.044	-0.217	-0.262	-0.015	-0.670	0.206	-0.105	0.096	-0.106	-0.133	-0.119	4
5	0.376	-0.103	-0.213	-0.306	0.064	-0.771	-0.036	-0.187	-0.077	-0.337	0.016	-0.103	5
6	0.250	0.337	-0.172	-0.490	0.284	-0.070	-0.199	0.163	0.451	0.361	0.010	0.161	6
7	-0.199	0.260	0.097	0.226	-0.124	0.385	0.097	0.656	-0.140	0.250	-0.009	0.237	7
8	0.284	0.145	0.295	0.150	0.253	0.414	0.097	-0.056	0.493	-0.112	0.017	0.188	8
9	0.401	0.269	0.229	-0.049	0.218	-0.270	-0.025	-0.049	0.150	-0.181	-0.167	-0.518	9
10	-0.135	0.087	0.056	-0.045	0.207	0.437	-0.254	-0.163	0.090	0.088	-0.028	0.442	10
11	-0.318	-0.374	-0.031	0.320	-0.400	-0.239	0.246	-0.064	-0.341	-0.121	-0.014	0.076	11
12	0.437	-0.053	-0.031	-0.108	0.212	-0.245	0.108	-0.317	0.258	0.253	0.026	-0.201	12
13	1.000	0.085	-0.099	-0.082	0.375	-0.314	0.169	0.041	0.203	-0.165	-0.062	-0.053	13
14	0.085	1.000	0.037	0.132	0.136	0.185	0.273	0.337	0.465	0.329	-0.260	0.180	14
15	-0.099	0.037	1.000	0.369	-0.357	0.382	0.004	0.093	0.051	-0.161	-0.083	-0.030	15
16	-0.082	0.132	0.369	1.000	-0.245	0.448	0.511	0.358	-0.136	-0.194	-0.145	0.026	16
17	0.375	0.136	-0.357	-0.245	1.000	-0.042	0.007	-0.149	0.359	0.061	0.024	0.196	17
18	-0.314	0.185	0.382	0.448	-0.042	1.000	0.045	0.270	0.159	0.249	0.077	0.182	18
19	0.169	0.273	0.004	0.511	0.007	0.045	1.000	0.245	0.295	-0.031	-0.096	0.209	19
20	0.041	0.337	0.093	0.358	-0.149	0.270	0.245	1.000	-0.022	0.106	-0.133	0.077	20
21	0.203	0.465	0.051	-0.136	0.359	0.159	0.295	-0.022	1.000	0.404	-0.143	0.264	21
22	-0.165	0.329	-0.161	-0.194	0.061	0.249	-0.031	0.106	0.404	1.000	-0.083	0.181	22
23	0.062	-0.260	-0.083	-0.145	0.024	0.077	-0.096	-0.133	-0.143	-0.083	1.000	-0.050	23
24	-0.053	0.180	-0.030	0.026	0.196	0.182	0.209	0.077	0.234	0.181	-0.050	1.000	24
25	-0.116	0.047	0.069	0.200	-0.186	0.176	-0.073	0.081	0.078	-0.096	0.324	-0.100	25
26	-0.141	0.012	0.155	0.219	0.074	0.376	-0.168	0.057	-0.014	-0.099	0.332	-0.090	26
27	0.285	-0.172	-0.046	-0.213	0.174	-0.580	0.275	-0.509	0.122	-0.140	-0.068	0.000	27
28	0.359	-0.247	0.100	-0.376	0.261	-0.209	-0.278	-0.304	0.069	0.013	0.044	0.237	28
29	0.335	-0.103	-0.345	-0.200	0.180	-0.681	0.223	-0.303	0.165	-0.034	-0.079	-0.113	29
30	0.143	-0.169	0.019	0.208	-0.126	-0.148	0.443	-0.318	0.134	-0.270	0.084	-0.134	30
31	-0.287	0.232	-0.162	0.071	-0.064	0.198	-0.099	0.157	-0.050	0.217	0.246	0.071	31
32	-0.149	-0.140	0.020	-0.085	-0.217	0.170	-0.295	0.128	0.084	0.426	0.360	-0.110	32
33	-0.026	-0.291	-0.118	0.187	-0.385	-0.233	0.224	0.125	-0.155	-0.132	0.239	-0.115	33

APPENDIX TABLE NO. 5. (Contd.)

	25	26	27	28	29	30	31	32	33
1	-0.482	-0.270	-0.168	-0.369	0.085	-0.134	0.215	0.000	-0.149
2	-0.212	0.237	0.042	-0.022	0.149	0.165	0.189	-0.202	0.000
3	-0.082	0.187	-0.510	-0.005	-0.287	-0.320	0.023	-0.013	0.078
4	-0.207	-0.417	0.571	0.227	0.697	0.176	-0.240	0.077	0.141
5	0.068	-0.233	0.498	0.168	0.503	0.256	-0.140	-0.031	0.070
6	0.237	-0.167	0.060	0.182	-0.007	-0.230	0.141	0.409	-0.153
7	-0.015	0.171	-0.597	-0.076	-0.457	-0.444	0.192	0.154	0.123
8	0.037	0.049	-0.073	0.101	-0.112	0.169	-0.287	-0.024	-0.044
9	-0.199	0.000	0.136	0.163	0.160	0.051	-0.355	-0.217	-0.117
10	-0.045	0.071	-0.191	0.220	-0.520	-0.127	-0.143	-0.111	-0.213
11	-0.061	-0.191	0.164	-0.097	0.338	0.047	0.010	0.115	0.439
12	0.186	-0.062	0.570	0.152	0.320	0.304	-0.221	0.210	-0.077
13	-0.116	-0.141	0.285	0.359	0.335	0.143	-0.287	-0.149	-0.026
14	0.047	0.012	-0.172	-0.247	-0.103	-0.169	0.232	-0.140	-0.291
15	0.069	0.155	-0.046	0.100	-0.345	0.019	-0.162	0.020	-0.118
16	0.200	0.219	-0.213	-0.376	-0.200	0.208	0.071	-0.085	0.187
17	-0.186	0.074	0.174	0.261	0.180	-0.126	-0.064	-0.217	-0.385
18	0.176	0.376	-0.580	-0.209	-0.681	-0.148	0.198	0.170	-0.233
19	-0.073	-0.168	0.275	-0.278	0.223	0.443	-0.099	-0.295	0.224
20	0.081	0.057	-0.509	-0.304	-0.303	-0.318	0.157	0.128	0.125
21	0.078	-0.014	0.122	0.069	0.165	0.134	-0.050	0.084	-0.155
22	-0.096	-0.099	-0.140	0.013	-0.034	-0.270	0.217	0.426	-0.132
23	0.324	0.332	-0.068	0.044	-0.079	0.084	0.246	0.360	0.239
24	-0.100	-0.090	0.000	0.237	-0.113	-0.134	0.071	-0.110	-0.115
25	1.000	0.494	-0.141	-0.253	-0.252	0.174	0.420	0.431	0.120
26	0.494	1.000	-0.522	-0.092	-0.383	-0.058	0.485	0.215	-0.081
27	-0.141	-0.522	1.000	0.126	0.597	0.341	-0.442	-0.188	-0.038
28	-0.253	-0.092	0.126	1.000	0.172	-0.087	-0.285	-0.048	-0.120
29	-0.252	-0.383	0.597	0.172	1.000	0.143	-0.158	-0.049	0.051
30	0.174	-0.058	0.341	-0.087	0.143	1.000	-0.108	-0.122	0.247
31	0.420	0.485	-0.442	-0.285	-0.158	-0.108	1.000	0.302	-0.200
32	0.431	0.215	-0.188	-0.048	-0.049	-0.122	0.302	1.000	0.161
33	0.120	-0.081	-0.038	-0.120	0.051	0.247	-0.200	0.161	1.000

APPENDIX TABLE NO. 6.

PRINCIPAL COMPONENTS

	1	2										
1	0.257	0.027	0.557	-0.510	-0.056	-0.148	0.167	0.359	0.097	0.182	-0.162	-0.110
2	-0.008	-0.154	0.442	0.034	0.267	0.041	0.569	-0.330	0.257	-0.198	-0.275	0.124
3	0.632	0.078	0.374	0.128	-0.133	0.013	-0.252	-0.380	0.051	0.073	0.256	-0.266
4	-0.736	-0.046	0.211	-0.282	0.093	0.016	0.187	-0.095	-0.081	-0.138	-0.225	-0.174
5	-0.740	-0.139	-0.119	-0.135	0.092	0.154	-0.010	-0.205	-0.341	-0.222	-0.030	0.062
6	-0.093	0.606	-0.229	-0.488	0.231	0.032	-0.296	-0.119	-0.240	-0.094	-0.156	0.071
7	0.664	-0.121	0.202	-0.253	-0.027	0.303	-0.185	-0.294	0.175	-0.045	0.007	0.334
8	0.159	0.537	0.063	0.534	0.109	-0.247	-0.244	-0.016	-0.068	0.161	-0.244	-0.340
9	-0.321	0.238	0.121	0.351	0.127	0.700	-0.001	0.092	0.213	-0.028	-0.128	-0.020
10	0.380	0.484	-0.118	0.211	-0.402	-0.381	0.029	-0.011	-0.167	0.008	-0.061	0.115
11	-0.124	-0.758	0.239	-0.173	-0.101	-0.240	-0.132	-0.192	0.153	-0.219	0.091	-0.179
12	-0.486	0.295	-0.163	0.099	0.400	-0.118	-0.110	0.164	0.363	0.043	0.430	0.247
13	-0.415	0.416	0.159	0.234	0.171	0.257	-0.227	-0.322	0.051	0.288	0.218	-0.043
14	0.273	0.443	0.381	-0.162	0.374	0.271	0.037	0.108	-0.298	-0.166	0.031	0.030
15	0.253	-0.023	-0.012	0.525	0.047	0.119	-0.250	0.212	0.184	-0.613	-0.172	0.013
16	0.426	-0.397	0.403	0.435	0.321	-0.053	-0.090	0.004	0.009	-0.061	0.233	-0.117
17	-0.166	0.632	0.117	0.004	0.006	0.031	0.445	-0.341	0.079	0.220	0.084	-0.002
18	0.842	0.180	-0.017	0.227	0.092	-0.203	0.011	0.171	0.139	-0.028	-0.060	-0.020
19	-0.061	-0.160	0.730	0.153	0.477	-0.240	-0.002	-0.086	-0.041	0.046	-0.009	0.213
20	0.506	-0.088	0.311	-0.238	0.224	0.406	-0.345	-0.123	-0.178	0.101	-0.060	0.127
21	-0.040	0.645	0.236	-0.031	0.468	-0.218	-0.039	0.021	0.066	-0.131	-0.222	-0.112
22	0.251	0.366	0.049	-0.607	0.137	-0.202	-0.112	0.244	0.424	-0.020	0.108	0.108
23	0.034	-0.160	-0.528	0.021	0.222	-0.197	0.152	-0.360	0.181	0.209	-0.298	0.160
24	0.271	0.274	0.291	-0.126	-0.199	-0.519	-0.029	-0.475	-0.211	-0.281	0.134	0.102
25	0.195	-0.120	-0.571	0.082	0.605	-0.099	-0.115	-0.092	-0.291	-0.098	0.211	-0.004
26	0.462	-0.061	-0.415	0.229	0.340	0.156	0.380	-0.260	0.124	-0.044	0.047	-0.165
27	-0.821	0.059	0.147	0.086	0.046	-0.282	-0.013	0.115	0.009	-0.172	0.161	0.171
28	-0.299	0.372	-0.156	0.108	-0.393	0.002	-0.120	-0.458	0.314	-0.274	-0.044	0.022
29	-0.761	-0.060	0.280	-0.229	0.108	-0.055	0.041	-0.103	0.155	0.027	0.092	-0.382
30	-0.368	-0.193	0.065	0.430	0.404	-0.372	0.078	0.125	-0.110	0.110	-0.129	0.130
31	0.409	-0.148	-0.247	-0.435	0.371	0.001	0.435	-0.084	-0.139	-0.101	0.100	-0.088
32	0.160	-0.042	-0.488	-0.416	0.363	-0.143	-0.376	-0.031	0.335	-0.063	-0.079	-0.192
33	-0.079	-0.524	0.023	0.048	0.124	-0.150	-0.462	-0.257	0.053	0.356	-0.261	0.122

APPENDIX TABLE 6. (Contd.)

1	0.193	0.099	-0.084	-0.062	0.056	0.076	-0.081	0.048	0.100	-0.020	-0.055	-0.095
2	0.006	0.014	-0.174	-0.026	-0.056	-0.049	-0.117	0.011	-0.024	0.123	0.078	0.049
3	-0.163	0.007	0.002	-0.103	0.079	0.024	-0.072	-0.109	-0.046	0.018	-0.054	0.035
4	0.143	0.122	-0.157	-0.203	-0.189	-0.002	0.104	-0.120	-0.020	-0.055	-0.028	0.074
5	-0.037	-0.024	-0.133	0.010	0.267	0.194	0.066	0.073	-0.057	-0.025	0.083	-0.096
6	0.099	-0.031	-0.107	0.018	0.010	-0.194	-0.089	0.023	-0.011	-0.085	0.045	-0.030
7	-0.030	-0.034	-0.016	0.065	0.095	-0.061	-0.015	-0.127	0.198	-0.025	0.064	-0.017
8	0.051	-0.110	0.054	0.031	0.097	0.046	-0.031	0.038	0.116	-0.083	0.050	0.026
9	-0.226	-0.054	-0.034	-0.136	0.155	-0.040	-0.015	-0.036	0.046	-0.017	-0.122	0.001
10	-0.060	0.076	-0.274	-0.302	-0.074	0.000	0.008	0.028	0.089	0.082	-0.029	-0.105
11	-0.106	-0.136	-0.058	0.012	0.083	-0.148	-0.001	-0.009	-0.029	-0.028	-0.035	-0.151
12	0.034	0.026	-0.090	-0.050	-0.017	0.119	-0.032	0.040	0.087	0.005	0.085	0.003
13	0.254	0.203	0.133	-0.041	-0.056	-0.077	-0.154	-0.035	-0.103	0.054	0.028	-0.123
14	-0.267	-0.027	0.178	-0.300	-0.002	-0.006	0.055	0.026	-0.021	-0.004	0.074	0.013
15	0.188	-0.036	0.106	0.014	-0.030	0.061	-0.156	0.109	0.010	-0.038	-0.033	-0.031
16	0.116	-0.011	-0.169	-0.152	0.048	-0.063	0.090	0.190	-0.041	0.029	0.029	0.028
17	0.076	-0.252	-0.229	0.101	0.107	-0.066	0.013	0.115	-0.030	-0.082	-0.069	0.041
18	0.163	-0.073	-0.022	0.037	0.034	-0.121	0.166	-0.065	-0.098	-0.025	0.096	-0.000
19	0.077	-0.016	0.093	0.012	-0.072	-0.027	0.128	-0.089	0.032	-0.133	-0.020	-0.046
20	0.299	-0.004	-0.067	0.111	-0.028	0.169	0.094	0.084	-0.011	0.085	-0.103	0.023
21	-0.250	-0.044	0.026	0.271	-0.089	0.014	0.013	-0.027	-0.041	0.131	-0.028	-0.071
22	-0.199	0.096	0.055	-0.032	0.035	0.053	0.077	0.098	-0.105	-0.054	-0.063	-0.007
23	0.141	-0.228	0.323	-0.256	0.067	0.053	0.082	0.014	-0.021	0.047	-0.045	-0.047
24	-0.001	-0.003	0.116	0.023	0.059	0.178	-0.092	-0.023	-0.005	-0.001	-0.022	0.065
25	-0.074	-0.064	-0.083	0.063	-0.077	-0.113	0.073	0.009	0.111	0.070	-0.102	-0.012
26	-0.074	0.103	-0.139	0.014	-0.190	0.228	0.001	-0.086	-0.011	-0.146	-0.008	-0.071
27	0.095	-0.251	0.005	-0.086	-0.068	-0.038	-0.119	-0.048	-0.008	-0.033	-0.086	0.040
28	0.033	0.328	0.062	0.033	-0.004	-0.094	0.204	0.111	0.049	-0.020	-0.029	0.015
29	0.003	-0.030	0.134	0.013	-0.035	0.050	0.099	0.049	0.161	0.070	0.057	0.006
30	-0.041	0.349	-0.028	0.048	0.274	-0.021	-0.008	-0.084	0.001	0.012	-0.051	0.035
31	0.079	0.218	0.185	-0.045	0.036	-0.120	-0.139	0.112	0.055	-0.047	-0.029	0.029
32	0.105	-0.037	-0.182	-0.108	0.148	0.042	-0.062	-0.113	-0.025	0.044	0.017	0.060
33	-0.324	0.051	-0.056	-0.005	-0.141	0.001	-0.124	0.190	-0.011	-0.062	0.029	0.035

APPENDIX TABLE NO. 7.

ROTATED FACTORS

CYCLES 10 ROTATIONS 173

LAST COLUMN = SUM OF SQS

1	0.086	0.042	0.208	-0.169	-0.370	0.019	0.150	0.528	0.478	0.314	0.213	-0.098
2	-0.101	-0.033	0.234	-0.070	0.039	-0.019	0.917	0.077	-0.033	-0.023	0.014	-0.034
3	0.359	0.163	-0.030	-0.482	-0.044	-0.313	-0.015	-0.065	-0.046	0.010	0.039	-0.659
4	-0.860	0.137	0.009	0.081	-0.212	0.043	0.030	0.023	0.057	0.002	-0.081	0.064
5	-0.797	-0.113	-0.039	0.119	0.098	-0.006	-0.031	-0.121	-0.280	-0.001	0.001	0.270
6	-0.296	0.437	-0.272	-0.282	0.173	-0.199	-0.233	-0.113	0.321	0.101	0.098	0.475
7	0.330	-0.251	-0.063	-0.802	0.004	-0.124	0.184	-0.006	0.164	-0.077	-0.103	-0.073
8	0.290	0.857	0.040	0.137	-0.075	-0.069	-0.134	-0.095	-0.138	-0.124	-0.054	-0.164
9	-0.150	0.211	-0.110	-0.105	-0.182	0.642	0.221	-0.387	-0.215	-0.210	0.221	0.054
10	0.561	0.284	-0.221	0.134	-0.158	-0.490	-0.129	0.047	-0.106	0.005	0.087	0.159
11	-0.390	-0.484	0.171	0.028	-0.050	-0.190	0.082	0.264	0.065	-0.169	-0.330	-0.487
12	-0.132	0.008	0.204	0.377	0.067	0.145	-0.096	-0.732	0.390	-0.012	0.053	0.161
13	-0.256	0.368	-0.008	-0.084	-0.130	0.126	-0.021	-0.697	-0.149	0.215	0.028	-0.121
14	0.001	0.350	0.229	-0.477	0.086	-0.021	0.067	0.011	0.115	0.005	0.581	0.143
15	0.231	0.099	0.021	-0.024	-0.004	0.098	0.037	-0.014	-0.078	-0.901	0.078	-0.057
16	0.262	-0.047	0.599	-0.190	0.139	0.005	0.058	0.017	-0.139	-0.281	0.008	-0.539
17	0.035	0.345	-0.204	0.112	-0.035	-0.127	0.419	-0.371	-0.035	0.481	0.272	0.075
18	0.796	0.237	0.092	-0.141	0.165	-0.114	0.018	0.189	0.189	-0.220	0.053	-0.128
19	-0.147	0.129	0.825	-0.157	-0.169	-0.149	0.328	-0.089	0.030	-0.004	-0.041	-0.121
20	0.080	0.034	0.180	-0.873	0.039	0.070	-0.082	0.090	0.043	0.012	-0.003	-0.058
21	-0.092	0.724	0.160	0.015	0.027	-0.119	0.194	-0.115	0.369	-0.073	0.201	0.137
22	0.153	0.038	-0.069	-0.140	-0.066	-0.102	-0.011	-0.008	0.896	0.107	0.136	0.095
23	0.125	0.008	-0.121	0.139	0.430	-0.004	0.230	-0.038	-0.006	0.121	-0.615	0.234
24	0.064	0.127	-0.009	-0.141	-0.068	-0.926	0.118	0.001	0.037	0.018	0.093	-0.097
25	0.039	0.038	0.199	-0.014	0.846	-0.057	-0.316	-0.119	-0.026	-0.127	-0.117	0.126
26	0.388	0.030	-0.126	-0.026	0.727	0.136	0.295	-0.030	-0.124	-0.044	-0.023	-0.139
27	-0.541	-0.058	0.252	0.523	-0.285	-0.114	-0.005	-0.338	0.036	-0.070	0.072	0.184
28	-0.154	0.111	-0.612	0.140	-0.210	-0.277	0.196	-0.418	-0.047	-0.201	-0.111	-0.002
29	-0.771	0.057	0.043	0.310	-0.164	0.113	0.142	-0.111	0.154	0.225	0.024	-0.278
30	-0.121	0.155	0.615	0.438	0.046	0.057	0.064	-0.082	-0.183	-0.076	-0.242	0.143
31	0.060	-0.141	-0.007	-0.139	0.718	-0.056	0.163	0.361	0.206	0.228	0.185	-0.010
32	-0.081	0.084	-0.216	-0.084	0.465	0.067	-0.218	0.045	0.623	-0.135	-0.385	-0.025
33	-0.150	-0.059	0.269	-0.191	-0.076	0.043	-0.123	0.016	-0.078	0.017	-0.799	-0.100